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## Utah Water Research Laboratory, Utah Center for Water Resources Research, A Program Overview

L. Douglas James

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**UTAH WATER RESEARCH LABORATORY**  
**UTAH CENTER FOR WATER RESOURCES RESEARCH**  
**A PROGRAM OVERVIEW**

April 30-May 2, 1986

Prepared for  
External Evaluation Team Organized by U.S. Geological Survey  
and  
Internal Review Team Organized by Utah State University  
by

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and  
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April 1986

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## ORGANIZATION OF PREPARED MATERIAL

This overview presents the water resources research program administered through the Utah Water Research Laboratory and the Utah Center for Water Resources Research. The documentation is prepared for an internal review by a faculty team organized by the Administration of Utah State University and an external review by a team organized by the U.S. Geological Survey as part of a national effort to evaluate the water research centers in every state over a 2-year period. These materials are prepared to stimulate discussion and spark innovative ideas for building an even stronger program. The UWRL/UCWRR administration sees opportunity in this assessment, welcomes the review teams as friends, and solicits constructive input.

The total UWRL/UCWRR program, not counting work in administratively separated but technically associated units, conducts water research exceeding \$2.5 million annually spread over about 100 projects in 10 program areas and involving about 300 people from the Director to undergraduate students hired on an hourly basis. This short overview gives highlights. Additional information on organization and goals is found in the Draft UWRL Mission Statement, on current activities in the most recent Annual Report, and on theoretical and applied contributions in numerous publications ranging from theoretical journals to popular brochures. All are open to those interested in probing.

The review and evaluation cover both UWRL and UCWRR. However, whereas the two units are operated as a whole and the smaller UCWRR program provides a more manageable focus within the space and time constraints on this review, the UCWRR projects are emphasized in the research descriptions to follow. They provide a microcosm of the total not unlike other components that could be considered.

The attached supporting materials provide:

1. Summary statements on goals, organization, people, facilities, and accomplishments, organized in response to the outline provided for the U.S. Geological Survey program review and including supporting tables on research budgets, funding agencies, and personnel.

2. A draft UWRL Mission Statement prepared as a research program planning document and organized to address issues raised by the USU Provost.

3. A proposal to build a center of excellence integrating expertise campus wide in expanding the water sciences as an example of a new research thrust.

4. Short reports on accomplishments by research projects since the UCWRR program came under USGS sponsorship.

5. Historical highlights.

6. Supplemental background materials:

a. Annual Report 1985 of the Utah Water Research Laboratory, Center for Water Resources Research, Agricultural and Irrigation Engineering, and Cooperative Fisheries Research Unit.

b. Utah State University Bulletin 1984-86 Catalog and Utah State University Bulletin 1985-1987 Graduate Catalog.

c. Water Resources Research Goals and Objectives for FY 1982 (UWRL General Series UWRL/G-81/01).

d. Brochures (USU In Fact 1986, 1978-85 Utah Water Research Laboratory Publications, Solving Today's Water Problems Through Research and Development, Solving Problems in Water Quality, Solving Problems in Hydraulics, Fluid Mechanics and Soil Erosion)

PART 1

SUMMARY STATEMENTS REQUESTED FOR USGS REVIEW

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## PART 1

### SUMMARY STATEMENTS REQUESTED FOR USGS REVIEW

#### SOME ISSUES FOR REVIEW

##### UWRL/UCWRR serves:

1. **The national interest** by obtaining funds from multiple sources to foster the productivity of water resources research talent in a unique facility and in an interdisciplinary problem-focused environment to make substantial contributions to water science and planning. For example, programs in the land disposal of hazardous wastes, cost effective cloud seeding, and "flood-and-mud" risk assessment on alluvial fans are producing results of great regional and national import.

2. **The state interest** by having a cadre of expertise, far beyond what a small state could otherwise support, that can be mobilized to address state and local problems. All three of the above examples illustrate research that was initiated with outside funds and produced contributions of great value to Utah.

3. **The University interest** by building an academic reputation for scholarship, a national reputation for accomplishment, and a local reputation for service.

##### Strengths of the Water Resources Research Program:

1. A long and continuing record of research accomplishment advancing the water sciences and the art of water resources planning.

2. A talented faculty, large enough to exceed the critical mass for productivity in a number of water research topics, working in a quality and well-equipped facility.

3. Consistent and diversified (from a number of sources on a variety of topics) external funding that doubles the activity that would otherwise be possible.

4. Flexible researchers who have listened to colleagues in other departments, worked on interdisciplinary projects, and earned respect for results achieved in many departments and colleges.

5. Positive relationships with the administrative structure of the university, the water agencies in state government, and federal and private sector water interests throughout Utah.

6. Regional and national leadership in water resources research program development.

Topics Where Discussion May Strengthen the Research Program:

1. The maintenance of productive working climates for individuals with joint appointments involving research for UWRL and teaching in an academic department.

2. Peer pressures that build because faculty give lesser recognition to researchers working outside the home academic department.

3. Administrative tendencies to feel lesser responsibility for people with research support when funding is sparse. Good researchers cover their salaries, and the hard money shifts toward other faculty. This burdens and reduces the productivity of the best researchers.

4. Criteria for providing continuing support to some faculty through UWRL and for limiting support for others to a project basis.

5. Preserving productive interactive communications among large numbers of faculty, supporting technicians, and students; providing incentives for stopping to reflect on how ideas from your neighbor's research can help your own.

6. Criteria for dedicating state (USGS) funds to basic scientific studies that lay groundwork for future applications rather than meeting immediate needs.

7. How UWRL/UCWRR resources might be better used within the national water research community to meet needs that will make more funding available at the national level.

## 1. RESEARCH RELEVANCE

Research is relevant as it makes short or long term contributions to understanding that improve water resources utilization, upgrade water quality, or reduce flood losses. Long term contributions lay the foundation for improving management practices and yet go unappreciated in an era when research priorities are set by users and funds are budgeted through mission agencies. Over time, user preoccupation with a "quick fix" becomes a barrier to relevance by widening the gap between the fundamental research underway in physics, chemistry, mathematics, biology, and other related sciences and engineering and planning applications. The path to continuing relevance is for research to develop "water science" that draws from the traditional sciences to upgrade water engineering from quantifying from empirical observations to quantifying from scientific laws. Because of the general nationwide weakening of support for the basic research essential for long term advances in water management, the UWRL and UCWRR are applying some resources to low-cost studies enlisting faculty throughout the university in basic research. (Part 3.) The bulk of the funds, however, continue to apply scientific principles to applied problems.

### Linkages to Advisory Groups

UWRL/UCWRR has advisory groups at several levels, and the faculty solicit additional informal collaboration on active studies. The formal, general, statewide advisory group is a Citizens Advisory Council (Table 1) selected to represent a broad range of needs for water resources research, as found in federal, state, and local agencies; public and private sectors; a statewide geographical distribution; and disciplinary perspectives. Two meetings are held with this group annually.

Ad hoc topical advisory councils are continually evolving. Recently active groups dealt with groundwater research and climatic and hydrologic data banking. Current groups, being organized or already active, are:

Utah Water Atlas Technical Steering Committee

Utah State Water Education Advisory Committee (in cooperation with the Man and Water program of the Western States Water Council)

Guidance Committee for forming a Center of Excellence in Water Information-Science-Control

Ad hoc Organizing Committee for a program in Scientific Hydrology

These groups provide specialized expertise for program development and assistance with technology transfer.

Advice on academic evaluation and interdisciplinary coordination comes through the University Water Resources Research Council (Table 2). This Council oversees external and colleague proposal and program reviews by identifying reviewers, assessing responses, and selecting deserving projects.

Many additional interactions occur between council members, their colleagues, and teams of researchers. UWRL/UCWRR faculty and agency staff are typically on a first-name basis. Most agencies have hired large numbers of USU graduates.



Table 1. Citizen Advisory Council members

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Joe Melling, CHAIRPERSON, Manager, Cedar City Corporation  
 Genevieve Atwood, VICE CHAIRPERSON, Director, Utah Geological and Mineral  
 Survey  
 Kenneth L. Alkema, Director, State Division of Environmental Health  
 D. Larry Anderson, Director, Division of Water Resources  
 Ted Arnow, District Chief, Water Resources Division, USGS  
 Sheldon H. Barker, CH2M Hill  
 Grace G. (Gigi) Brandt, League of Women Voters  
 Wayne D. Criddle, Clyde-Criddle-Woodward, Inc. (retired)  
 Ray J. Davis, J. Reuben Clark Law School, Brigham Young University  
 Dee C. Hansen, Executive Director, Department of Natural Resources  
 Leonard H. Johnson, NER Consultants  
 Lynn S. Ludlow, General Manager, Central Utah Water Conservancy District  
 (retired)  
 Gayle F. McKeachnie, Representative, Utah State Legislature  
 Robert Morgan, State Engineer, Division of Water Rights  
 Ray Nielsen, Representative, Utah State Legislature  
 Darrell Nish, Chief, Resource Analysis, Division of Wildlife Resources  
 J. Kent Taylor, Forest Supervisor, Fish Lake National Forest

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Table 2. University Water Resources Research Council.

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A. Bruce Bishop, CHAIRPERSON, Dean, College of Engineering  
 Thadis W. Box, Dean, College of Natural Resources  
 C. Elmer Clark, Associate Director, Agricultural Experiment Station  
 Robert A. Hoover, Dean, College of Humanities, Arts, and Social Sciences  
 Thomas I. Isenhour, Dean, College of Science  
 L. Douglas James, Director, UWRL/UCWRR  
 Bartell C. Jensen, Vice President for Research  
 Doyle J. Matthews, Dean, College of Agriculture and Director, Agricultural  
 Experiment Station  
 Frederic H. Wagner, Director, Ecology Center

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### Linkages to Identified Problems

The long-standing top priority problems are water supply, salinity control, and drinking water safety. Cloud seeding had top priority as a method for water supply augmentation. In 1983, a series of wet years turned the problem emphasis to flooding, debris flows, and the rising level of the Great Salt Lake. The UWRL/UCWRR program immediately moved to meet the need with new research directions. The situation was also exciting scientifically because measurements could be made of hydrologic processes that had not occurred for a century. An annual rainfall total of 37 inches in an area that had not had more than 23 inches in over 110 years triggers a multitude of hydrologic happenings. UWRL/UCWRR priorities are summarized in Table 3.

The effectiveness of the UWRL/UCWRR research identification process in recognizing long term needs and developing projects to meet them is illustrated by two studies that began during the 1977 drought. At that time, the UCWRR funded projects developing modeling capability to quantify probabilities for rising Great Salt Lake levels and to route mud flows from basic hydraulics. Both results have found practical risk assessment applications since the wet period began.

### Research Funding

The attached funding history (Table 4) displays UWRL/UCWRR budget sources over the last 24 years. Table 5 shows the breakdown of funding by agency in FY 1985. Table 6 lists agencies and companies that have supported projects over the last 20 years. Factors that contribute to maintaining this level of funding and diversity of sponsors are:

1. A strong commitment by the State of Utah to provide a continuing funding base. This supplements academic assignments to insure 9 months of support for core faculty, preserves the critical mass through lean periods, maintains supporting administrative services, funds assistantships for deserving students, and covers experimental expenses for exploratory studies.

2. Additional support from the state agencies in funding studies on current problems. Such funds have been a major support source in recent years for flood-related research. In earlier years, the Utah Division of Water Resources provided a support base for cloud-seeding research.

3. A practical bent that has been able to transform principles from the theoretical literature to applications meeting immediate needs within user constraints.

4. An ability to organize resources to meet sponsor deadlines on short-term studies in excellent hydraulics and water quality facilities.

Table 3.

## Problem Area Priorities

	March 1980	December 1980	December 1981	December 1982	December 1983	December 1984	December 1985
I. Atmospheric Water Resources							
A. Winter Cloud Seeding	VH	VH	VH	VH	VH	H	M
B. Hail Suppression	L	L	L	L	L		
II. Hydraulics, Fluid Mechanics, and Soil Erosion							
A. Erosion Control	M	M	M	M	M	H	H
B. Fluid Mechanics	M	M	M	M	M	M	M
C. Model Studies and Hydraulic Testing	M	M	M	M	M	M	M
III. Hydroclimatic Measurements							
A. Farm Water Management Instrumentation	VH	VH	VH	VH	VH	H	H
B. Automated Data Collection Instrumentation	L	L	L	L	L	VH	H
C. Systems Development						VH	VH
IV. Hydrologic Analysis							
A. Salinity	VH	VH	VH	VH	VH		
B. Demands for Rural, Urban and Instream Use	M	M	M	M	M	H	H
C. Watershed Management	H	H	H	H	H		
D. The Great Salt Lake	L	L	L	L	M	H	VH
E. Flood Control	M	M	M	M	H	H	VH
F. Hydrologic Processes and Data Management	H	H	H	H	H		
V. Water and Energy							
A. Water and Fossil Fuel Resources	VH	VH	VH	VH	H		
B. Hydroelectric Power	M	M	M	M	M	M	M
C. Nonstructural Alternatives for Water and Energy Conservation	L	L	L	L	L		
D. Water and Renewable Energy Resources	L	L	M	M	M		
E. Solar Power						M	M

Priority Designations: VH = very high, H = high, M = medium and L = low.

Table 3. Continued.

	March 1980	December 1980	December 1981	December 1982	December 1983	December 1984	December 1985
VI. Water Resources Planning and Management							
A. Criteria for Quantifying Unpriced Values	H	H	M	M	M	L	H
B. Methods for Evaluating Water Management Alternatives	M	M	M	M	M	M	M
C. Risk-Benefit Assessment	L	L	L	L	L		
D. Institutional, Organizational and Legal Analyses	M	M	M	M	M	L	L
E. Financial Analysis	L	L	L	L	L	L	L
F. Local Water Systems Operation and Management	M	M	M	M	M		
VII. Water Quality Management							
A. Quality of Natural Waters	H	H	H	H	H	H	H
B. Environmental Impacts of Energy Development	VH	VH	VH	VH	H	M	M
C. Potable Water Protection	VH	VH	VH	VH	VH	VH	VH
D. Wastewater Management	H	H	H	H	H	H	H
VIII. Groundwater Resources							
A. Groundwater Hydrology and Management	VH	VH	VH	VH	VH	H	H
B. Groundwater Protection	H	H	H	H	H	H	H
C. Special Groundwater Uses	H	H	H	H	H		
D. Salinity						VH	VH
IX. Information Dissemination and Technology Transfer	VH	VH	H	H	H	H	H

Priority Designations: VH = very high, H = high, M = medium and L = low.

Table 4.

## UWRL Annual Expenditures by Source

Fiscal Year	Utah Funds		Contracts and Grants			Totals
	State Appropriation	Mineral Lease	Other Sponsored at UWRL	U.S. Geological Survey*		
				Sponsored at UWRL	Sponsored Outside UWRL	
1964	14,255	39,309	81,685			135,249
1965	28,035	108,654	7,691	42,815	32,185	219,380
1966	25,015	159,416	186,448	56,215	111,285	538,379
1967	25,031	102,708	405,412	97,010	77,200	707,361
1968	64,560	91,417	501,649	112,910	74,756	845,292
1969	84,782	93,189	551,860	106,228	92,675	928,734
1970	90,227	99,810	678,394	165,300	95,009	1,128,740
1971	98,103	100,404	877,529	130,935	76,503	1,283,474
1972	105,002	105,009	933,337	139,046	110,284	1,392,678
1973	120,127	121,606	952,453	132,757	283,062	1,610,005
1974	319,000	125,663	920,985	239,935	223,797	1,829,380
1975	335,620	165,956	936,866	236,229	265,064	1,939,735
1976	431,920	165,368	543,090	291,061	250,302	1,681,741
1977	517,550	165,000	572,363	180,192	307,561	1,742,666
1978	611,400	195,000	673,769	184,105	120,671	1,784,945
1979	603,900	317,320	475,556	324,071	148,755	1,869,602
1980	532,702	374,255	578,678	357,144	143,752	1,986,531
1981	654,366	442,451	805,367	265,000	64,000	2,231,184
1982	650,787	473,157	707,902	246,600	25,000	2,103,446
1983	579,397	914,346	810,851	202,781	9,000	2,516,375
1984	191,700	1,101,135	808,302	120,108	-0-	2,221,245
1985	537,006	737,240	1,121,405	109,027	-0-	2,504,678
1986	611,500	776,300	1,300,000	109,000	-0-	2,796,800
1987	723,400	675,000	1,500,000	109,000	50,000	3,185,580

\*Cooperative State-Federal Program previously housed in the Office of Water Research and Technology

Table 5.

FY:85 Annual Expenditures on  
Contracts and Grants

U.S. GOVERNMENT AGENCIES

U.S. Geological Survey	\$ 46,242
Agency for International Development	17,085
National Science Foundation	66,362
Environmental Protection Agency	389,085
Forest Service	3,992
National Oceanic and Atmospheric Administration	2,690
Agricultural Research Service, Boise, Idaho	39,282
U.S. Bureau of Land Management	455
U.S. Bureau of Reclamation	64,177
U.S. Army Corps of Engineers	<u>29,651</u>

Subtotal	\$ 659,021
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STATE AND LOCAL ENTITIES

Division of Water Resources	\$ 198,651
Utah State Planning Board	3,310
Utah State University (V.P. Research)	13,058
Local Cities	<u>1,701</u>

Subtotal	\$ 216,720
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PRIVATE SECTOR SOURCES

	\$ 117,497
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MISCELLANEOUS CORPORATE RESEARCH

Utah State Planning Board	6,720
Funded through Utah State University Foundation (Mueller Valve, Capes-Vulcan, Engineering Science, Fowler Pump, Valtek, Bahannan-Huston, Terragua Resources, Xomox, Environmental Research and Technology)	121,447

Subtotal	\$ 128,167
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TOTAL	<u>\$1,121,405</u>
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Table 6. Continued.

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U. S. Air Force  
U. S. Army Corps of Engineers  
U. S. Bureau of Land Management  
U. S. Bureau of Reclamation  
U. S. Department of Health  
U. S. Environmental Protection Agency  
U. S. Forest Service  
U. S. Geological Survey  
U. S. Navy  
U. S. Water Resources Council  
U.S.-Israel Binational Agricultural Research Development  
University of Nevada  
University of Utah  
University of Washington  
Utah Consortium for Energy Research and Education  
Utah Department of Employment Security  
Utah Division of Great Salt Lake  
Utah Division of Health  
Utah Division of Water Resources  
Utah Division of Water Rights  
Utah Energy Office  
Utah Geological and Mineral Survey  
Utah Power & Light Company  
Utah State Division of Social Services  
Utah State University Foundation  
Utah Water and Power Board  
Utah-Idaho Sugar Company  
Vaughn Hansen Associates  
Vice President for Research, USU  
Virginia Electric Power Company  
Wasatch National Forest, U. S. Dept. of Agriculture  
Western Ecosystems  
Williams Brothers Engineering Company

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### Studies Funded by Utah Agencies

1. Developing information to use in planning level controls at the Great Salt Lake. Agency funds supported:

a. A senior UWRL researcher to work in the Office of the Utah Division of Water Resources during the critical rise period to assist in the technical review and coordination of studies on control alternatives.

b. Technical studies on

- 1) hydrologic forecasting,
- 2) reconnaissance assessment of control alternatives,
- 3) examination of a potential pumped-storage scheme between lake waters and storage in a higher closed basin,
- 4) assessment of odors expected near urban areas as the rising lake freshens and biologic activity commences in municipal wastes that were pickled as they accumulated over a century.

c. Water quality modeling to assess problems that may occur in reservoirs used to develop additional water supplies and add to consumptive use.

2. A cooperative study program with the Utah Geological and Mineral Survey to determine the soil water accumulations and pore pressures that develop in mountainsides and generate landslides and debris flows so as to be able to improve effective warning and control programs.

3. Organizing citizen participation in planning reservoir projects for Bear River Basin development for water supply, hydrologic power generation, and consumptive use for lake level control.

4. Cooperative research and monitoring to develop an effective cloud seeding program to augment winter precipitation in mountain snowpacks.

5. Developing water educational materials for elementary schools (K-6) and conducting training workshops that have shown over 4000 Utah teachers how to use them effectively in classroom situations.

### Interaction with State Agencies in Cooperative Ventures

1. Active participation of the Director on the Utah Council of Science and Technology, an advisory body to the Governor. Example activities include heading a Task Force for the Governor, through the Utah Council on Science and Technology, to recommend long and short term directions for lake management, and advisory meetings with the Governor and Congressmen on water management and water quality control.

2. Membership on councils setting state policies for groundwater quality protection, drinking water safety, and home disposal of residential wastes.

3. Membership on general advisory councils to the Division of Water Resources and to the Geological and Mineral Survey.

4. Joint effort with the Utah Division of Comprehensive Emergency Management agency in arranging flights through Senator Hatch during 1984 to monitor snowpack and earth instability conditions in the higher mountain



ranges in order to be able to give advanced warning of avalanches and debris flows.

#### Support from the Private Sector

1. **Hydraulic testing.** Hydraulic devices are tested, calibrated or evaluated and other hydraulic studies are performed to help manufacturers improve and users select more efficient designs.

2. **Water quality testing.** Water quality constituents are identified with modern sophisticated instrumentation for 60 chemical and 10 bacteriological parameters in a certified laboratory to provide information for research support and clients with specialized water quality problems.

3. **Erosion testing.** A variety of erosion control products have been tested with the UWRL rainfall simulation facility since its construction in 1970. Current testing emphasizes evaluating the effectiveness of commercial products for mitigating erosion caused by rainfall and running water without inhibiting establishment of protective vegetative cover.

4. **Lake level forecasting.** The hydrologic lake level forecasting model has been applied to determine the risk for managers engaged in making decisions on whether and how to protect private properties.

## 2. RESEARCH QUALITY

The primary evidence of research quality is its contribution to science and practice. Long term contributions come through peer use in making long term advances in the basic sciences and scientific advancements to the planning art. Short term contributions come through immediate applications to improve water management practice. A quality research program should mix the two, stimulating interaction between people of scientific and applied bent, to keep scientists mindful of practical problems and engineer-planners mindful of underlying theory.

Some samples of peer use to advance understanding and provide practical help are found in UWRL/UCWRR projects:

Analysis of data on peak water use justified changes in the minimum-pipe-size standards for the design of rural and recreational domestic water supply systems. Adoption of a revised standard by the Utah Division of Health will save billions of dollars over time.

Crop water use models were developed to optimize management practices to control water and salinity levels in the soil for crop production. The model has achieved widespread use by the Food and Agricultural Organization (FAO) of the United Nations to increase food production around the world and is being disseminated through on-going workshops.

Application of energy accounting as a tool for evaluating investments in water recreation found that more energy is used in recreation than in agriculture or any other single business. The quantified uses provide a starting point for energy saving policies during periods of shortage.

### Researcher Credentials

Research projects are directly managed by active faculty whose credentials are evaluated during project selection. Brief statements of expertise are found in Table 7, and complete resumes are available. The recent emphasis in UCWRR awards has been on helping younger faculty in academic departments initiate foundation studies for productive careers in water resources research. Programmatic thrusts (sensing and data management for water control, scientific hydrology, and water education as examples) are initiated as UWRL programs.

### Reporting Quality

Research reporting employs different media in different roles. Research approaches, initial results, and problem assessments can be discussed for feedback at professional meetings. Scientific advances and innovating engineering designs are presented in refereed journals. UWRL research reports document material that is too voluminous or data intensive for journal publication. Journal length restrictions sometimes only give room for "advertisement" where other researchers and users need numerical data and procedural details.

Table 7. Biosketches of Principal Investigators.

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**L. Douglas James**

Dr. James (PhD, Stanford University, Civil Engineering) is Director of the Utah Water Research Laboratory and Center for Water Resources Research, and Professor of Civil and Environmental Engineering. He has directed many research projects on hydrology and water resources planning with particular emphasis on flood problems, hydrologic modeling and using hydrologic models to quantify economic tradeoffs in water resources, and has chaired national and state committees concerning such topics as federal participation in water resources research and flood hazards.

**William J. Grenney**

Dr. Grenney (PhD, Oregon State University, Civil and Environmental Engineering) is Professor and Department Head, Civil and Environmental Engineering, and Associate Director, Utah Water Research Laboratory. He has over 10 years experience in mathematical modeling of natural systems and physical/chemical processes for water treatment, and is extensively involved in developing applications of microcomputer systems for water resources management.

**Adams, V. Dean**

Dr. Adams (PhD, Utah State University, Organic Chemistry) is now Director, Center for the Management, Utilization and Protection of Water Resources, Tennessee Technological University, Cookeville, Tennessee. As a researcher and Director of the Water Quality Laboratory at UWRL, he made numerous contributions in organic and inorganic analysis methods development, and evaluation of natural systems, toxic and hazardous wastes, heavy metals, and impacts of energy development of water quality.

**Jay M. Bagley**

Dr. Bagley (PhD, Stanford University, Hydrology/Water Resources Engineering) is Professor of Civil Engineering. His expertise is in hydrology and water resources engineering. He has teaching, research, and administration experience in hydrology, irrigation, and water resources planning and management; consulting experience on water planning and management problems related to agriculture, mining, energy and industrial development; and industrial experience in design, development and testing of sprinkler irrigation equipment and systems.

**J. Clair Batty**

Dr. Batty (Sc.D, Massachusetts Institute of Technology, Mechanical Engineering) is Professor, Mechanical Engineering Department. His expertise is in applications of thermodynamics to improving water resources management in energy applications. He has authored over 60 technical publications on these topics, and supervised research by more than 30 MS and PhD candidates.

Table 7. Continued.

**Gail E. Bingham**

Dr. Bingham (PhD, Cornell University, Micrometeorology) is State Climatologist and Associate Professor, Soil Science and Biometeorology Department. His research emphasis has been on studies of the effects of air pollutants, water and other environmental stresses on the urinary productivity of crop and natural plant systems; micrometeorological processes of energy exchange in the atmosphere; development of instrumentation for advancement of environmental studies; atmospheric aerosol of near earth laser propagation and plant growth; and climatological studies of plant growth and yield.

**A. Bruce Bishop**

Dr. Bishop (PhD, Stanford University, Civil Engineering), is Dean of the College of Engineering. His expertise is in engineering economics, planning, and systems, with research and teaching in resource and public work systems for managing energy, water, environment and transportation problems with particular emphasis on the analysis, planning and evaluation of environmental, economic and social interrelations in decision making.

**David S. Bowles**

Dr. Bowles (PhD, Utah State University, Civil and Environmental Engineering), is Professor of Civil and Environmental Engineering. His expertise is in stochastic hydrologic modeling particularly oriented toward risk assessment. His numerous publications contribute to such topics as low flow modeling in small steep watersheds, steady-state river quality modeling by sequential extended Kalman filters, and random differential equations in water quality modeling.

**Duane G. Chadwick**

Mr. Chadwick (MS, University of Washington, Electrical Engineering) is Associate Professor of Electrical Engineering. His research in instrumentation development has addressed a cost effective solar powered water pump, solar energy collection and storage, development of a large-scale weather parameter telemetry network for use in mountainous regions, watershed simulation studies on a hybrid computer, and other hydrologic instrumentation for water quantity and quality measurement.

**Calvin G. Clyde**

Dr. Clyde (PhD, University of California at Berkeley, Civil Engineering) is Professor of Civil Engineering. He is an experienced administrator and researcher, widely published in groundwater engineering, hydraulics and hydrology with applications for water resources planning. His expertise covers groundwater modeling, contamination, and salinity buildup; hydraulic model studies; hydroelectric power and geothermal energy development; viscous sublayer mechanics; turbulence; erosion control, and sediment transport.

**James P. Dobrowolski**

Dr. Dobrowolski (PhD, Texas A&M University, Watershed Science) is Assistant Professor of Watershed Science, Department of Range Science. His area of expertise is in soil-water-plant relations and nutrient cycling on arid lands.

Table 7. Continued.

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**William J. Doucette**

Dr. Doucette (PhD, University of Wisconsin, Water Chemistry) is Assistant Professor of Civil and Environmental Engineering. His principal research expertise is on the use of physical, chemical, and structural parameters in modeling the fate of organic compounds in the environment.

**Lynn M. Dudley**

Dr. Dudley (PhD, Washington State University, Soil Chemistry) is Assistant Professor in the Soil Science and Biometeorology Department. His expertise is in soil physical chemistry, with interests in solution electro-chemistry, kinetics and thermodynamics of weathering processes, and transport processes.

**Christopher J. Duffy**

Dr. Duffy (PhD, New Mexico Institute of Mining and Technology, Geoscience/Groundwater Hydrology) is Assistant Professor, Civil and Environmental Engineering. His expertise is in geoscience and groundwater hydrology, emphasizing the problems of arid regions, with teaching and research in the stochastic analysis of groundwater movement and transport.

**R. Ryan Dupont**

Dr. Dupont (PhD, University of Kansas, Environmental Health Engineering) is Research Assistant Professor presently developing applications of microcomputers for toxic and hazardous waste management and related environmental engineering design. His expertise is in biological treatment processes, industrial waste pretreatment, wastewater treatment plant operations and evaluations, and air pollution, particularly as related to the volatilization of organics from groundwater.

**Donna H. Falkenberg**

Ms. Falkenberg (BS, Utah State University, Journalism) is Editor at the Utah Water Research Laboratory, and Editor of *Aquarius Newsletter*. She is co-editor of two scientific books, author or co-author of several publications, and has edited more than 600 project reports, occasional papers, manuals, and proceedings.

**R. J. Hanks**

Dr. Hanks (PhD, University of Wisconsin, Soils) is Professor of Soil Science in the Department of Soil Science and Biometeorology. His expertise is in water flow in soil, soil-water-plant relations, and crop production modelling. He has over 30 years research and teaching experience.

**Frank W. Haws**

Mr. Haws (MS, Utah State University, Civil Engineering) is Research Engineer. His 20 years of research and consulting experience cover such diverse topics as consumptive use and water requirements; analysis of hydropower potential and design of hydropower facilities; erosion during highway construction; overcoming problems of small private water companies in maintaining safe drinking water service; hydrologic inventories and land use studies; and state water planning.

Table 7. Continued.

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**Geoffrey E. Hill**

Dr. Hill (PhD, Penn. State University, Meteorology) is Research Professor. His expertise is in the development of weather modification systems through field experiments and evaluations. The studies employ numerical modeling of cumulus convection for cloud seeding delivery. His recent studies have included remote control of hydrometeorological devices, super-cooled liquid water measurements, seeding signatures, and development of evaluation techniques for assessment of cloud seeding effects.

**Lawrence E. Hipps**

Dr. Hipps (PhD, University of California at Davis, Atmospheric Science) is Assistant Professor of Biometeorology, Soil Science and Biometeorology Department. His current research is in reconstruction of ecosystems in arid lands, and assessing the water and free energy requirements for crop growth.

**Daniel H. Hoggan**

Dr. Hoggan (PhD, Utah State University, Civil Engineering) is Professor of Civil and Environmental Engineering. His expertise is in water resources planning and management. His recent research has been concentrating on hydrologic modeling with the U. S. Army corps of Engineers, Hydrologic Engineering Center. His research has examined flood damage mitigation in Utah, a unified river basin system of state water rights management, management of groundwater recharge areas, analysis of water management perceptions of legislators, flood hazards delineation in Utah, state financing of water projects, and automated data acquisition, transmission, and analysis systems.

**Trevor C. Hughes**

Dr. Hughes (PhD, Utah State University, Civil Engineering) is Professor of Civil and Environmental Engineering. His expertise is in water resource systems optimization and municipal water system planning models. His recent research is in management of salinity in the Colorado Basin, drought management analysis and policy design, regional planning of rural water supply systems, and economic analysis of alternative water conservation concepts. He consults internationally on irrigation reservoir operation rule methodology applications.

**C. Earl Israelsen**

Dr. Israelsen (PhD, University of Arizona, Hydrology) is Professor of Civil Engineering. He has 25 years of experience in physical modeling and erosion control. He is adept at coordinating and managing large-scale interdisciplinary projects of national and international scope, and is active in technology transfer as Acting Associate Director of International Office for Water Education, and past president and member of directing board of International Erosion Control Association.

**Eugene K. Israelsen**

Mr. Israelsen (MS, Utah State University, Water Resources and Hydrology) is Senior Research Engineer. He provides research support expertise for modeling hydrologic, water resources and water quality systems.

Table 7. Continued.

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**Roland W. Jeppson**

Dr. Jeppson (PhD, Stanford University, Civil Engineering, Fluid Mechanics) is a noted expert in numerical methods for hydraulic and hydrologic modeling; vadose zone flow and local pore pressures; groundwater movement; pipe network analysis; hydraulic analysis of debris flows; and simulation of watershed hydrologic response.

**Jerome J. Jurinak**

Dr. Jurinak (PhD, Utah State University, Soils) is Professor of Soil Science (Chemistry), Soil Science and Biometeorology Department. His expertise is in salt-affected soils, reclamation, irrigation water quality, heavy metal chemistry in soils, and environmental assessment.

**Joan McLean**

Ms. McLean (MS, University of California at Davis, Soil Chemistry) is Research Scientist/Chemist. She is experienced in soil, water, and wastewater chemical analysis, and in the evaluation of the behavior of heavy metals in soil systems.

**J.J. Messer**

Dr. Messer (PhD, University of Florida, Environmental Engineering Sciences) is Research Associate Professor. His expertise is in natural stream and lake systems including nutrient and heavy metal biogeochemistry. His research explores the environmental impacts of acid precipitation, nitrogen and phosphorus dynamics in lake sediments, eutrophication control, and impacts of fossil fuel development on aquatic systems.

**James P. McCalpin**

Dr. McCalpin (PhD, Colorado School of Mines, Geology) is Assistant Professor, Department of Geology. His expertise is in Quaternary geology and geologic hazards; tectonic geomorphology, Quaternary stratigraphy, soil stratigraphy, remote sensing applications in Quaternary and engineering geology, and geologic information for governmental policy planning.

**Rangesan Narayanan**

Dr. Narayanan (PhD, Utah State University, Economics) is now an Associate Professor at the University of Nevada at Reno. While in the Economics Department at USU he taught and directed research in econometrics and mathematical economics as applied to land and water use. Some applications were in the development of a comprehensive Upper Colorado River Basin model for analyzing downstream salinity impacts and methodology for balancing energy production and environmental quality protection at small hydroelectric sites.

**Robert D. R. Parker**

Dr. Parker (PhD, University of Minnesota, Environmental Health) is Associate Professor of Biology. He is an environmental health specialist and biologist with research training in water quality and environmental toxicology.

Table 7. Continued.

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**William J. Rahmeyer**

Dr. Rahmeyer (PhD, Colorado State University, Hydraulics) is Assistant Professor of Civil and Environmental Engineering. His expertise includes model studies of hydraulic structures, scour and erosion studies, basic research in open and closed conduit flow, and hydromachinery testing.

**J. Paul Riley**

Dr. Riley (PhD, Utah State University, Civil Engineering) is Professor of Civil Engineering and Head, Division of Water Resources Engineering. His expertise is in applications of hydrology in the management of water resource systems. He has broad background in computer simulation techniques for water resource management, and has broad international consulting experience.

**Alberta J. Seierstad**

Ms. Seierstad (BS, University of Wisconsin, Chemistry) is Research Scientist/Chemist, and Supervisor for the Water Quality Laboratory. She has expertise in water quality chemical analysis methods development, chemical and toxicology aspects of fossil fuel process, and aquatic bioassay applications.

**Uri Shani**

Dr. Shani (PhD, Hebrew University, Israel, Soil Physics) is a Post-Doctoral Soil Physicist with the Department of Soil Science and Biometeorology. His expertise is in soil physics. He has published on the mutual effect of salinity level and oxygen content on plant yield, and on drip irrigation.

**Raghubir P. Sharma**

Dr. Sharma (PhD, University of Minnesota, Pharmacology) is Professor of Pharmacology and Toxicology. His research activities and expertise include environmental monitoring using animal models, the toxicity of environmental pollutants, health effects and mechanisms, and minor use drugs and pesticides, and studies to improve food safety by control of natural toxicants.

**Judith L. Sims**

Ms. Sims (MS, University of North Carolina, Environmental Biology; MS, North Carolina State University, Soil Science) is Research Soil Scientist at UWRL. She assists in research on the evaluation of high loading rates and assimilative capacities for land treatment of hazardous wastes, volatilization of hazardous constituents at hazardous waste land treatment sites, fate of chlorinated hydrocarbons in land treatment systems, and evaluating the mound system of soil absorption of household wastes.

**Ronald C. Sims**

Dr. Sims (PhD, North Carolina State University at Raleigh, Biological and Agricultural Engineering) is Associate Professor and Head, Division of Environmental Engineering. His expertise is in design and management of hazardous waste land treatment systems, industrial wastewater treatment process design and evaluation, and sand filters and other low technology water treatment systems.



Table 7. Continued.

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**Darwin L. Sorensen**

Dr. Sorensen (PhD, Colorado State University, Microbiology) is Research Assistant Professor. He has extensive research experience in the microbiology of soils, mine land reclamation, and nitrogen cycling processes in arid areas, and in evaluating the behavior and fate of toxic and hazardous waste constituents in soil systems and impacts of hazardous waste on soil microbial processes.

**J. Paul Tullis**

Dr. Tullis (PhD, Utah State University, Civil Engineering), Professor of Civil Engineering, is an internationally recognized expert in the analysis, design, and testing of hydraulic structures. His expertise emphasizes cavitation, hydraulic transients, vortex modeling, drag reduction, and boundary layer development. Applications are found in the testing, calibration and performance improvement of valves, pumps, turbines, and flow meters; and model studies of side channel and overflow spillways.

**Lyman S. Willardson**

Dr. Willardson (PhD, Ohio State University, Agricultural Engineering) is Professor in the Agricultural and Irrigation Engineering Department. His expertise is in irrigation drainage and salinity control with particular application to farm water management in saline soils. Recent projects have examined the potential for using wastewater from electrical power plants for irrigation, clogging of drainlines by mechanical, chemical and biological actions, and effects on salinity of the Colorado River caused by shifts in water use from agriculture to cooling for thermoelectric power generation.

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For quality documentation, the UWRL publication policy provides reviews for all research reports by involving academic peers in checking for scientific validity and agency users commenting on practical applicability. Editorial capabilities are used to polish research presentations (including conference papers and journal articles). The results are then printed and distributed with about 3,000 copies UWRL/UCWRR reports being mailed out annually.

#### Publications Record

The research faculty publish actively. Senior individuals have long lists of publications. The publication of research results from studies actively supported during the last four years (69 publications) is suggestive even though limited by the time lags in writing and nursing contributions through the publication process. Nevertheless, the 25 projects completed during the past 4 years, generated 20 articles, and 10 more are in the process of being written for publication in professional journals. Also, the recent research has been supported in small units that sometimes make it more appropriate for researchers to synthesize collective results than report the findings of individual projects. Example publication records include:

1. Incorporation of empirical energy loss data into momentum equations (A-053) made a fundamental contribution in deriving flow equations for debris flow that proved very timely in assessing the debris hazards that occurred shortly afterwards. Project findings were picked up by the Forest Service and expanded as described in followup publications that contributed to risk assessment in 1983-84. Extensions of that work have already been published in five papers.

2. Laboratory-based computer modeling quantifying in-channel salt release and salt-sediment transport in the Colorado River Basin (B-172), produced two ASCE proceedings papers in 1984, and two additional articles being prepared for 1986 publication. The proof that surface salt sources contribute relatively little to the total loading helped direct future studies toward underground sources.

3. Results from a study (B-187) of the response of freshwater ecosystems to allochthonous organic material (largely crude oils) are still being disseminated through articles in preparation for the Water Resources Bulletin and for the Journal of Hydrobiology. The study demonstrated the importance of nutrient immobilization and gave guidelines for protecting mountain lakes from possible petroleum spills.

#### Administrative Regard for Research Program

The Director interacts closely with the top administrators of the university, all of whom hold the water resources research program in high regard. Evidences of their support are:

1. UWRL participation in activities to strengthen the research and academic programs of the university as a whole.

2. Appointments of the Director to committees for formulating University policy on research matters. (University Research Committee, Committee to

Evaluate Compensation for Extra Contractual Services, Committee on Reorganizing the Research Foundation, etc.)

3. Use of UWRL/UCWRR research achievements in lists of University accomplishments prepared by the administration for publicity purposes.

4. Consultation on water related matters (e.g., probable effects of the rising level of the Great Salt Lake on the University budget).

### 3. RESEARCH COORDINATION

#### Programmatic Themes

UWRL/UCWRR, the academic departments, and related research and training centers (Ecology Center, International Office for Water Education (IOWE), International Irrigation Center (IIC), Engineering Experiment Station, Fish and Wildlife Research Unit, etc.) have placed a strong priority on water resources research. Projects are parts of programs (see UWRL Annual Report) involving faculty and student interactions.

#### Multiple Disciplines

Over the last 10 years, the UCWRR research program has involved 14 academic departments (listed in Table 8) at Utah State. The last four years have involved 12 (excepting Mechanical Engineering and Philosophy). Civil engineering is the largest single participant, and the departments of Economics and Soils are not far behind (Table 8). The consistency of participation by core faculty has been another program strong point.

The number of faculty active in UCWRR studies has been waning as available program funds continue to decline in constant dollars. The social sciences (including economics) have been particularly hard hit by declining opportunities for continuing funding.

#### Interdisciplinary Studies

Many projects bring individuals from two or more departments into new intellectual relationships of working together to respond to some current problem. Nine studies completed in the past four years involved principal investigators in two or more departments. Four current projects are interdisciplinary.

#### Inter-university

Utah State University is the only university in the state with a strong, general graduate program in water resources. Brigham Young University has a strong undergraduate program and sufficient graduate work for regular interaction. The University of Utah has strong programs in mining, meteorology, water law, etc., but it has not developed research strength in water because of state policy against using the limited funds to establish competing areas of excellence. Weber State College is primarily an undergraduate institution, but it does have some very capable faculty who are active in water studies. The UCWRR maintains contact with faculty on all three campuses through a mailing list of Associates, and by having program coordinators (Alan J. Dayley, Associate Director, Office for Research and Development, Weber State College; Upmanu Lall, Assistant Professor, Civil Engineering, University of Utah; and A. Woodruff Miller, Associate Professor, Civil Engineering, Brigham Young University) on each campus.

Table 8. Academic departments of principal investigators.

	Number of Faculty by Year									
	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Civil Engineering	10	18	24	26	24	20	22	19	10	9
Geology										1
Soils	1	4	3	5	3	3	2	1	1	2
Ag and Irrigation Engineering		1	1	1				1	1	1
Biology	1	1	2	2		1	1	1		1
Animal, Dairy & Veterinary Sciences										1
Economics	11	6	5	7	7	7	7	2	1	
Sociology	3	4	3	2	1	1	1	1		
Political Science	1	1				1	1	1		
Forestry	2	2	2	2	1	1	1			
Statistics				1	1		1			
Fisheries				1	1	1	1			
Mechanical Engineering	1	1		1						
Philosophy	1	2	2							
<hr/>										
Graduate Students	50	50	32	49	41	38	33	19	9	6

### Inter-agency

Joint studies with agencies and private sector firms:

1. The USGS-State cooperative program for research on soil-water conditions generating landslides and debris flows. The UWRL/UCWRR and the Utah Geological and Mineral Survey are cooperating in event mapping, field monitoring, and modeling.

2. The Agricultural Research Service, USDA, Northwest Watershed Research Center at Boise and UWRL are jointly launching a long-term study of how subsurface catchment structure affects baseflow runoff generation.

3. Harza Engineering of Chicago, Illinois, has joined with UWRL/UCWRR in developing proposals for overseas training in water resources planning and management at the river basin scale. Funding is expected shortly for a major long-term program.

Multiple funding sources:

The total UWRL/UCWRR research program, as summarized in Tables 4 and 5, currently attracts funding from 10 agencies. The external funds double to triple (depending on the year) the state research funds as they are spent, largely pursuing the mission goals of a funding agency. State funds support research topics holding a high priority within the state. (Table 3 lists the priorities.) They are also used for matching, for research initiation, and to support foundational studies and syntheses of advances for expertise building. This ability to shift funds to match changing needs in long term program building is one of the major strengths of the program.

### Regional

The Director of the UWRL/UCWRR chairs the regional group of Center Directors (Consortium of Water Institute Directors also including Arizona, California, Colorado, Nevada, and New Mexico) and is in charge of maintaining a statement of regional research priorities. Utah has also actively joined with universities in other states in regional projects. For example, in the drought year of 1977 Utah State organized the western states in collecting and disseminating ideas for water conservation in a widely disseminated newsletter exchanging experiences in dealing with the drought. Other regional projects estimated 1) the economic impact of salinity in the Colorado River on downstream water users, and 2) crop water production functions and the effects of salinity in a variety of climatic situations.

#### 4. INFORMATION TRANSFER

##### Awareness

UWRL publishes an **Aquarius** newsletter that describes the goals of new projects and the results of old ones to potential users. Brochures have been developed to publicize program capabilities. Press releases publicize findings, and TV coverage has been obtained for issues of general concern.

##### Technology Transfer

The UWRL Library collection of 30,000 publications is available to patrons. For example, a retired BYU professor wanting information on Utah Lake found only one publication (a UWRL one), at the BYU library, while we were able to furnish him with twelve related publications. UWRL library is widely used by students and faculty.

Conferences were held on aquatic resources related to the Colorado River in 1981, on flood related problems in Utah in 1984, and on the rising Great Salt Lake in 1985. Published proceedings are available for all three. An annual series of workshops was recently initiated with the Idaho Water and Energy Resources Research Institute on irrigation technology.

##### Responses to Various User Needs

UWRL/UCWRR faculty participate in short courses given by the International Irrigation Center bringing about 300 students annually from around the world to Utah State for training related to water management in agriculture in dry climates.

Training sessions have also been held for Division of Water Resources and Corps of Engineers personnel on hazard assessment from rising lake levels.

Research information exchange sessions are regularly held with the staff of state and federal agencies.

##### General Education

A two-volume set of evidence has been prepared and distributed around the country to help high schoolers with the 1985-86 national debate topic on a federal policy for water pollution control. Water education materials have been prepared and distributed for use in the science curricula in elementary schools. In Utah over 4,000 teachers have attended workshops for instruction on teaching water subjects for K through 8th grade. Present plans are to prepare additional materials for use in the secondary schools and to extending the teacher training into other states.

### Cooperation with Statewide Communication Network

The Agricultural Extension Service uses a statewide TV network with telephone feedback for interacting with agents. UWRL has assisted by presenting information on water management during droughts. The exchange initiated a project on home water purifiers.

The single most important information item for agriculture during drought is soil moisture. UWRL cooperated with the College of Agriculture in establishing a soil water measurement network that is now regularly collecting data (Annual Report, p. 113) for research and management applications.

The Water Information-Science-Control program (Annual Report, p. 103) is organizing a research effort to make spatially and temporally variable data available for hydrologic and water management research. Platforms have been installed for data collection for transmission to satellites. An operating downlink receives the data and relays desired information to users around the state. The system is expanding toward the delivery of spatially and temporarily varied data for research and real time management. For example, the delivery of information to personal computers through phone connections offers the promise of making nonstructural programs effective.

UWRL/UCWRR are cooperating with various state and federal agencies in the preparation of a water atlas to provide descriptive information that will become readily available for use in water planning in Utah (Annual Report, p. 116). A great deal of additional data is being compiled in computer files.

### Expertise

UWRL/UCWRR maintain an editor on staff, supported by computerized drafting and secretarial services. Additional resources for multimedia presentations are available on campus and regularly used. The media capability has worked in preparing sound-visual shows on water rights, the hydrologic cycle of water, etc.



## 5. TRAINING

The multidisciplinary Utah water research program places students for training in many academic departments with a variety of programs and requirements. Water related studies tend to be a University strength in all disciplines. Consequently, the water resources research projects have been able to choose from good students, and multidisciplinary curricula have exposed them to water sciences and planning from a variety of academic viewpoints.

Program graduates have distinguished themselves in their careers. Table 9 shows the current employment of former students whose research was supported by UCWRR projects (over 10 years because most of the students in the last four years are either still in school or too recently graduated to have established positions). A total of 139 students, an average of 14 annually, have had their graduate studies supported entirely or in part by the program. Of these, 14 are faculty members at other American Universities, 23 are engineers or scientists working for consulting firms, 11 are with state or local governments, 12 work for the U.S. government, 9 work for industry, 9 are employed overseas (mostly as faculty in universities in their native countries; 9 are still in school at USU, and 20 are in other occupations or at other schools. A present location could not be determined for 32.

For USU as a whole, 32 percent (fall quarter 1985) of the graduate students are from out of state. Eighty-nine percent of the students working in the UWRL/UCWRR program are from out of state, demonstrating the extent to which the water-oriented academic studies and water resources research attract people from around the nation and world to Utah State University.

USU water students are distinguished by awards received. They have won more UCOWR awards for outstanding dissertations than any of the other universities, averaging one of the three awards annually. Other recognitions in the last four years include American Water Works Association Academic Achievement awards and Utah Water Pollution Control Association student paper contest winners.

Table 9. Current job locations for former students (1976-1985).

Faculty Members

Albrecht, Don (77), Faculty, Texas A & M  
 Buckhouse, John (76), Assoc. Dean, Rangeland, Oregon State Univ.  
 Davidoff, B. (82), Prof. Agronomy Dept., Louisiana State Univ.  
 Finney, Brad (77), Faculty, Humboldt State Univ., CA  
 Franklin, Douglas (82), Faculty, Univ. of Nevada, Reno  
 Kress, Mike (82), Res. Assoc. Forestry Dept., Okla. State Univ.  
 Malone, Ronald F. (78), Prof. Louisiana State University  
 McKee, Mac (79), Faculty, Humboldt State Univ., CA  
 Morgan, Ward (79), Faculty, Drexell University, PA  
 Narayanan, Rangesan (77), Faculty, Univ. of Nevada, Reno  
 Nezafati, Hooshang (81), Prof. Univ. of Evansville, IN  
 Snyder, Don (80), Faculty, Econ. Dept., Utah State University  
 Sorenson, W.M. (79), Engineering Experiment Station, Urbana, IL  
 Werner, Martin D. (82), Faculty, Univ., San Antonio, TX

Consulting Firms

Bell, David A. (77), Vice Pres., EFI, Inc., UT  
 Burns, Susan (84), Camp, Dresser, McKee, Phoenix, AZ  
 Cameron, James C. (78), Consulting Firm  
 Cissell, Jeffrey A. (80), Stan and Webster, Boston MS  
 Elliott, Jerry T. (76), Consulting Firm, Boise, ID  
 Franckiewicz, James (77), Consulting Firm, San Francisco, CA  
 Hicken, Boyd (78), CH2M Hill  
 Hinchee, Rob (82), Ecological Analyst, Consulting Firm, Sparks MD  
 Humphries, William (81), Hydrologist, Consulting Firm, Denver CO  
 James, W. Robert (80), Brice, Petrides, Donahou, Waterloo, IA  
 Kemp, Michael C. (78), CH2M Hill  
 Kuo, Alex (80), Consulting Firm, California  
 Martin, Delbert G. (78), CH2M Hill  
 Nemanich, Frank (81), Env. Eng. Consulting Firm, Greenville NC  
 Righellis, Anthony D. (78), Consulting Firm, Portland, OR  
 Rupp, Gretchen (81), Tetra Tech, Inc. Lafayette, CA  
 Sangani, Sanjay (85), Hydrologist, GeoTrends, Boulder, CO  
 Stoddard, Thomas C. (81), Engineer, East Coast  
 Sepehr, Mansour (85), Consulting Firm, Salt Lake City  
 Torpy, Michael F. (79), Argon (DOE), Chicago, ILL  
 Tweet, Thomas M. (76), Biowest, Logan, UT  
 Wang, H.C. S. (80), Consulting Firm, California  
 Wightman, Daria (80), CH2M Hill

State or Local Governments

Ballard, Spencer A. (76), Transp. Planning, Dade County, FL  
 Coache, Bob (81), Water Res. Dept., City of Las Vegas, NV  
 Campbell, Craig (78), State Agency, Washington State  
 Dickson, Judy (79), South Bay Municipal Utilities District,  
 San Francisco, CA  
 Rao K., Baskar (81), Hydrologist, State Engineer's Office, NM

Table 9. Continued.

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State or Local Governments (continued)

Selby, Douglas A. (83), Dep. Director Clark County Sanitation District, Las Vegas, NV  
Sizemore, Kenneth (77), Regional Planner, St. George, UT area  
Solomon, Norman (77), Transportation Dept. Salem, OR  
Turna, Kuldeep S. (77), Virginia Alcohol Commission Board  
Van Luik, Abraham (78), Nuclear Waste Management & Salinity  
Whitehead, John (81), Hydrologist, Div. of Oil, Gas & Mining, Salt Lake City, UT

Federal Government

Adams, Dennis J. (79), Project Leader, Dugway Proving Grounds UT  
Bernard, David R. (76), Dept. Fisheries, Alaska  
Fifield, Jerald S. (79), USBR, Denver, CO  
Hotchkiss, Roland H. (80), Tennessee Valley Authority  
Houston, David G. (76), Reg. Director, USBR, Sacramento, CA  
Jensen, Donald T. (80), Water Supply Forecasting for Western States regional group, Portland, OR  
LaBau, David (78) Corps of Engineers, Seattle, WA  
Lyons, Steve (76), Hydrologist, Forest Service, Alaska  
Maloney, Steel (84), Forest Service, North West area  
Pugner, Paul E. (77), Corps of Engineers, Sacramento, CA  
Springer, Everett (82), Res. Hydroloist, Los Alamos National Lab.  
Wark, John (77) WSC, Gunnison, CO

Industry

Amirfathi, Parvanah (83), Utah Power & Light Company, UT  
Chen, C.L. (79), Aerospace Industry, CA  
Fakhraei, Hamid (83), Utah Power & Light Company  
Ging, Steven E. (79), Irrigation Scheduling Company, Idaho  
Kincaid, Charles T. (78), Battelle Institute, Richland, WA  
Pate, John A. (79), Project Manager, General Electric, MASS  
Peterson, Stanley R. (80), Water Quality Group, Battelle  
Perman, Catherine (79), City Services, Oil Corporation, OK  
Spendlove, Alan (77), HydroTech, Logan, UT

Foreign Employment

Cheng, Ming Chen (76), Assoc. Prof, Univ of Taiwan  
Dadkhah, M. (78), Faculty, Univ of Tehran, Iran  
DeLeon, Alfredo (83), Faculty, Merida, Venezuela  
Jones, Craig (76), Manitoba Hydro Power Authority, Winnipeg CAN  
Kono, Yukio (77), Japan  
Maase, David (79), teaching in Germany  
Padungchai, Sumol (79), EXON, in Thailand  
Rodrigues, Salvador (83), Faculty, Panama  
Sharma, S. C. (79), Director, Research Laboratory, India

Table 9. Continued.

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Current Students at USU

Azimi-Zonooz, Ali (85)  
 Cole, Lynnette (85)  
 Conner, Kevin (82)  
 Finnie John (85)  
 Greider, Thomas (83) (just finished PhD)  
 Hamner, Rex (82)  
 Hsieh, Gin-Chang (85)  
 Madany, John (81)  
 Shen, I-Fu (85)

Other Occupations or Continuing Education

Campion, Barbara D. (81), Graduate student, U of U  
 Cannon, Joel R. (76), Teacher  
 Freitas, Christopher J. (78), Graduate student, Stanford Univ., CA  
 Howell, Craig (81), Medical school  
 Jaynes, Richard (77), Lawyer, U.S. Army, Hawaii  
 Jenison, Raymond L. (79), Military Intelligence, CIA  
 Kartchner, Eugene (82), Pre Med student  
 Kimball, Kirk (78), Intermountain Health Care, Salt Lake City  
 Larson, Dean (77), not employed, New Mexico  
 Lee, Terry (81), Cook  
 Lee, Kun (83), Graduate school, U of U  
 Lei, Stephen (81), Graduate school, Germany  
 Mahmood, Ramzi (81), Graduate student  
 Mok, Bruce (83), Env. Eng. student  
 Olsen, D. R. (79), just graduated from Texas A&M (PhD)  
 Ridinger, David D. (79), Technician, Med Center, Salt Lake City  
 Roberts, Barbara (78), Environ. Lawyer, Salt Lake City  
 Stube, John C. (76), Pastor, Provo, UT  
 Thelin, Richard (82), Lawyer, U.S. Marines  
 Winters, Nancy (82), Aquatic Ecology

Not Able to Determine (most were undergraduates)

Allred, Dale (77)	Miller, C. W. (79)
Bamatraf, A. M. (79)	Milovich, Rose M. (80)
Barnard, Thomas E. (77)	Munjal, Rajeev (79)
Bich, Joel P. (81)	Nussbaum, M.T. (84)
Bickel, Ken (81)	Nyby, Denise (81)
Gertsel, G. (82)	Packard, Kathleen (78)
Ghorashian, J. (81)	Packer, Phil (76)
Hancey, David (83)	Reeder, Martin (78)
Higginson, Kevin (81)	Riggs, Lynn (78)
Hoagland, John (76)	Robbins, Charles R. (79)
Iverson, David (76)	Runke, Henry M. (76)
Jones, Anthony A. (76)	Smith, Phillip J. (76)
Martin, Tim (81)	Stoddard, Scott (84)
McNeill, P. (79)	Tew, Roger (76)
McNutt, P. (78)	Watkins, Sharon (77)
Metzger, Tom (81)	Wright, W.P. (78)

## 6. ACCREDITATION

Utah State University is accredited by the Northwest Association of Secondary and Higher Schools and is listed by the following additional accrediting agencies in fields related to water resources.

EAC/ABET Engineering Accreditation Commission of the Accreditation  
Board for Engineering and Technology  
Society of American Foresters  
American Chemical Society  
American Society of Landscape Architects  
Engineering Council for Professional Development  
Soil Science Society of America

More information on accreditations of Utah State University may be obtained from the Provost's Office.

## 7. PHYSICAL FACILITIES

The Utah Water Research Laboratory is one of the outstanding water resources research facilities in the country. The George Dewey Clyde building, beside the Logan River, contains a 102,000 square-feet of laboratory space. The original building was specially equipped for hydraulic modeling and testing. Present facilities also include a well instrumented water quality laboratory; electronic instrumentation to measure hydraulic, hydrologic, and climatic events; a well-equipped shop with expert craftsmen for fabricating experimental apparatus and developing specialized instrumentation; a library; publication services which supply editorial, typesetting, graphic arts, and drafting needs; secretarial services which utilize modern word processing equipment; and a business office to provide purchasing, accounting, and billing support. A research facility for the Fisheries Research Unit is also housed in the building. (Annual Report, p. 27-31.)

### Supporting and Other Related Laboratories

**Agricultural Experiment Station**--conducts research needed to conserve and manage natural resources, to produce and prepare food and fiber, and to develop and improve rural homes and rural living.

**Engineering Experiment Station**--houses a variety of studies furthering engineering in the sciences, engineering arts, and engineering education.

**Space Engineering Center**--concentrates on the development of techniques and instrumentation for in situ and remote sensing and on the analysis and interpretation of measurement results, with special expertise in the measurement of auroras, airglow, the ionosphere, atmospheric pollution, infrared imaging, geophysical remote sensing, and natural resource censusing.

**Ecology Center**--involves over 50 active associates engaged in research and training ranging from alpine to salt desert environments, both aquatic and terrestrial communities, in such facilities as the Bear Lake Biology Laboratory, the USU forest facilities, the Green Canyon Ecology Station, the Logan River Biology Laboratories, and the Snowville Ecology Station.

**Fisheries Research Unit**--emphasizes responses of fish populations to alterations for the aquatic environment; behavior and habitat requirements of fish and aquatic invertebrates; manipulation of undesirable fish populations; genetic studies of fish populations; and threatened and endangered species.

**Institute of Land Rehabilitation**--provides a research service to public and private concerns in all aspects of land rehabilitation. It also works to increase and participate in land rehabilitation problems and research.

**Wildlife Research Unit**--focuses on resource management in waterfowl and marshland ecology; big game habitat, populations, and habitat requirements; upland game bird ecology and habitat; biometrics; estimation theory; habitat requirements of nongame species; and conservation education.

## Libraries

**UWRL:** The Utah Water Research Laboratory houses a library of research reports and supporting material (30,000 documents) from sources not commonly housed in the main University library. Documents have been obtained from all the state water institutes over the last 20 years. Users come from the main campus, state agencies, and private patrons, with many requests from out of state.

**University:** The University Library houses 940,000 bound and 177,000 serial volumes. Current serial subscriptions number 7150. Overall, the collection must be rated as poor, and the lack of holdings are a particular handicap to scientifically oriented research. Many researchers have gone toward planning studies that have a lesser requirement for published references.

## Computer Facilities

UWRL has time-sharing access to six mainframe computers (four DEC VAX 11/780's, an IBM 4341, and a UNIVAC 1108), 9 Leading Edges, and numerous other miscellaneous personal computers. Hardline access to the VAX computers is available through 16 CRT terminals located throughout the building. Access to the IBM and UNIVAC computers is by telephone modem. The mainframe computers are equipped with many popular canned routines such as IMSL, SPSS, SAS, MINITAB, and REDEQL, as well as many locally produced programs. UWRL also has a remote line printer, a Tektronix 4006-1 graphics terminal, and integrative digital XY plotter, electronic digitizer, and several 48 to 64 microcomputers. The Department of Civil Engineering maintains two DEC 11/25-34 minicomputers and has recently obtained 13 DEC PC 350's for faculty use. Dialup access is available through Telemet to the Dialog data base for on line data and literature searching, and programming consultation and repair services are available both at UWRL and through the USU computer service. A PDP-11/70 computer with DECNET connects to the VAX system, and dial up connections are available to NCAR/CRAY systems in Boulder, Colorado.

## WISC - Data Banking Capabilities

A Water Information-Science-Control Center joins new research teams in remote sensing and data management with established teams in hydrology, optimization modeling, and water resources management. Instrumentation is being developed for field flow and water quality measurements. Included are a software package, a satellite receiving dish, and several field stations. The system will almost instantaneously transmit data via geostationary satellite from remote field stations to a USU computer for analysis and storage. The facility provides an important tie to a leading local industry, electronic instrumentation for hydrologic measurement.

## Unique Facilities

**Hydraulics Laboratory**--The 102,000 square-foot laboratory building contains large open areas specially equipped for hydraulics research and testing. Experimental areas are served by a variety of flumes, channels, pumps, pipelines, equipment, and instrumentation. Water is supplied by a 48-inch pipe with a capacity of 170 cfs (a maximum velocity without pumping of

13.5 feet per second). Ample water is always available from the Logan River. Spillways, high pressure radial, slide, and fixed well gates, valves, energy dissipation structures, stilling basins, pumping pits, penstocks, pipe manifolds, and open channel measuring devices have been modeled for projects in many countries.

**Water Quality Laboratory**--The Utah Water Research Laboratory has extensive analytical research capabilities. In order to assure the quality of data obtained in the performance of research, the UWRL maintains State of Utah and U.S. Environmental Protection Agency certification for its environmental quality laboratory. A 12,000 square foot facility provides space and equipment to conduct laboratory bench-scale and pilot plant studies, and to perform analytical and bioassay tests for water quality and environmental management research. The facility includes a 4800-square foot wet chemistry laboratory which serves as the center for analytical instrumentation, a microbiology complex for bacterial, algae, and viral research; four constant temperature bioassay and research laboratories; and a soil waste treatability laboratory.

**Rainfall Simulator**--This one of a kind facility permits the investigation of plant-soil-water interactions and relationships over a wide range of slopes, rainfall rates, light, wind, and soils, under controlled and convenient laboratory conditions. It consists of 500 individually controlled electrically-operated valves arranged in a 20 ft x 20 ft matrix, each valve controlling flow for simulating rainfall rates varying from 1 to 31 inches per hour.

**RIFFLE**--The Research Installation for Fate and Effects in Lotic Environments is a facility for ecosystem-level studies of chemicals in mountain streams. The facility contains eight pool-and-riffle stream microcosms house in a 20 ft x 60 ft greenhouse. The streams can be configured to provide a variety of conditions found in cold hardwater mountain streams. The facilities are available for conducting static fish, algal and terrestrial bioassays.

**Mountain Watershed Field Facility**--A mountain area at about 8000 feet is instrumented for weather data, pore pressure, and soil water content and movement rates. The goal is to build a strong data base for better understanding of the processes generating land slides and debris flows.

**Cooperative Use of Instrumented Watershed with ARS, Boise**--The Agricultural Research Service, Northwest Watershed Research Center, Boise, and UWRL/UCWRR researchers are jointly launching a long-term study using the ARS experimental watershed. There are two main objectives. The first is to characterize multidimensional hydrologic processes and their relation to the physical characteristics of landforms. The second is to implement a physically based saturated-unsaturated three dimensional flow model for the simulation of the hydrologic response of the experimental site.

**Dairy Research Farm**--A unique facility utilizing a waste management system, developed by UWRL researchers. The two-stage lagoon facility incorporates into it treated wastewater, recycle, and flushing, for animal waste transport and treatment.



**Salt Gradient Solar Pond**--Two ponds are connected to provide solar heat to a greenhouse for research and demonstration purposes.

**Hazardous Waste Facility**--Houses research activities on the detection and identification of pollutants, evaluation of sources and fates of pollutants, and the development of treatment technologies for control of pollutants.

#### UCWRR Equipment

Relatively little equipment has been purchased from UCWRR projects. The primary exception is the Riffle facility described above. A few small water quality instruments were also purchased. Other funds were generally used to purchase equipment and instrumentation. UCWRR funds generally went to direct research expenditures. A complete listing of equipment purchases from UCWRR projects can be made available.

## 8. INTERDISCIPLINARY RELATIONSHIPS

Interdisciplinary relationships are intertwined through program administration, academic seminars and curricula, research development, and project performance and review. At the administrative level, the Deans of the Colleges with active academic programs in water resources are over research policy and project selection. A number of interdisciplinary seminars occur regularly and graduate students take courses from several departments. As can easily be seen by reviewing the lists of proposals (Table 10) and Short Reports on Project Accomplishments (Part 4), the involvement of researchers from multiple departments is the rule rather than the exception. Six active projects involve faculty from groundwater hydrology, geology, civil and environmental engineering, agricultural engineering, aenvironmental engineering, soil chemistry, soil science, zoology, toxicology, and environmental health.

The best evidence of productive interdisciplinary interaction is found in research results that could never have been achieved from a single discipline. Examples in the UWRL/UCWRR program are found in the following projects:

a. JER-201. Faculty from groundwater hydrology in civil engineering and from soil science are working together to quantify how geochemical interactions within arid region soils affect the salt loading of effluent streams and aggregate to determine the salinity of such major rivers as the Colorado.

b. JER-202. Faculty and students from economics and civil engineering joined to review the modeling approaches that have been employed for water resources management in the Colorado River Basin in order to identify the most promising in terms of technical capabilities, data availability, and institutional acceptability.

c. JER-306. Researchers from environmental engineering, soil chemistry, soil science, groundwater hydrology, and zoology are joined in exploring ways to protect groundwater by immobilizing hazardous metals generated by industrial wastes, accidental or illegal disposal, or possibly natural sources.

Table 10. Proposals submitted through the Utah Water Research Laboratory.

Proposal Title	Personnel	SUBMITTED		Pending	Funded	Rejected
		Date	Agency			
Effects of Complexation with Spent Oil Shale Leachate on Heavy Metal Bioaccumulation	J.J. Messer	5-22-81	EPA			X
Conducting Tests Kerotest Manufacturing Corporation	J.P. Tullis	2-25-81	Kerotest Manf. Corp.			X
Assessment of Precipitation Augmentation Potential in Winter Orographic Cloud Systems	G.E. Hill	8-19-81	NSF		X	
Millstone Nuclear Power Station Unit 3 "The Circulating Water Pumpwell Hydraulic Model Study"	J.P. Tullis	8-21-81	Stone & Webster Eng. Corp. MA			X
Cavitation Tests on a 3-Inc Venturi	J.P. Tullis	9-14-81	Stone & Webster Eng. Corp.			X
Investigation of Operational Aspects of the NOAA-Type Dual Frequency Microwave Radiometer	G.E. Hill	10-22-81	NOAA	X		
Water Quality Modeling of Stream-Aquifer Systems via Spectral Analysis & Stochastic Differential Equations	C.J. Duffy	12-15-81	NSF	X		
Costs & Benefits of Irrigation Water Conservation in the Western United States	CWIC	12-15-81	OWRT	X		
Testing a 6" venturi meter with cold water at Reynolds Number up to $1.9 \times 10^6$	P. Tullis	10-02-81	Babcock & Wilcox			X
IIASA "Modeling Policy Alternatives for Motivating Industrial Use of Low Quality Water"	IIASA, Hughes	12-01-81	IIASA	X		
Evaluating Selected Mulches Under Simulated Rain	C.E. Israelsen	01-12-82	Conwed Corporation		X	
Additional Modeling of Tarbella Tunnel 3	J.P. Tullis	12-11-81	Tippetts-Abbett-McCarthy Stratton		X	
Hanford Generating Plant Hydraulic Modeling Study	J.P. Tullis C.G. Clyde	01-27-82	Washington Public Power			X
Generalized Harmonic Analysis of Groundwater Level Fluctuations	C.J. Duffy	01-15-82	Faculty Research Grant		X	
Land Treatment Technology for Oil Shale Wastewaters-Treatability Studies	R.C. Sims	01-15-82	Faculty Research Grant		X	

Table 10. Continued.

Proposal Title	Personnel	SUBMITTED		Pending	Funded	Rejected
		Date	Agency			
Harvesting Allelopathic Chemicals from Wastewater Lagoons for Algal Species Control	J.J. Messer	01-15-82	Faculty Research Grant			X
Feasibility of Introducing Risk Analysis in Policy Formulation etc.	D.H. Hoggan	01-15-82	Faculty Research Grant			X
Testing quotation number 1169 dated 2-10-81	J.P. Tullis	02-04-82	Kerotest Manufact. Corp.			X
Evaluating Scaling Criteria for Vortex Modeling (additional to T-81-1 and WG-324).	J.P. Tullis	02-04-82	Sandia Laboratories			X
Proposal for the Training of Two Participants from OMVS at Utah State University	Bill Grenney John Keith Paul Riley	2-24-82	USAID Washington, D.C.		X	
Innovative Methods to Reduce Cost of Extending Life of Ovsolescent or Abandoned Hydropower Plants	Frank Haws E.K. Israelsen	2-26-82	Utah Power & Light		X	
NOAA/STATE Cooperative project in area of Beaver, UT 1983	G. E. Hill	4-05-82	Paul Summers			X
Model Study of a Turbine Bypass (Howell-Bunger) Valve	J. P. Tullis	4-15-82	CH <sub>2</sub> M Hill, Denver Water Board			
Utah State Prison 30 Day Geothermal Well Flow Test	C. G. Clyde	04-28-82	Utah State, Div. Fac. Constr. & Mngmt.			X
Subcontractor to Utah Div. of Water Resources--NOAA Federal/State Progr. winter of 1982-83.	G. E. Hill	04-28-82	NOAA Federal/State Pro. UT. Div. of Wtr. Res.			X
A Proposal for an Interdisciplinary Research Workshop on Transfers of Appropriative System Water Right and Related Issues (Tentative October 1982)	L. D. James R. G. Kraynick J. L. Huffman	05-10-82	Western Rural Dev. Cntr Natr. Res. Law Inst. Res. for the Future, Inc			
Nitrogen Mineralization and Nitri-fication Potential of Mine Spoils (RFP-28-C2-219)	D.L. Sorensen J.J. Messer	05-21-82	U.S. Forest Service		X	
Wastewater Treatment Technology Evaluation and Application Study	R.C. Sims V.D. Adams	07-04-82	U.S. EPA			X
Engineering Design and Management Information for Land Treatment Systems Receiving Wastes Containing Recalcitrant & Mutagenic Organic Priority Pollutants.	R.C. Sims V.D. Adams J.J. Jurinak D.L. Sorensen J.L. Sims	05-27-82	EPA			X

Table 10. Continued.

Proposal Title	Personnel	SUBMITTED		Pending	Funded	Rejected
		Date	Agency			
Highway Maintenance Impacts to Water Quality	C.E. Israelsen C.J. Duffy D.L. Sorensen J.L. Sims J.E. Fletcher V.D. Adams J.J. Messer	05-27-82	Dept. of transportation Federal Highway Admin.			X
Federal Highway Administration Proposal (RFP still) ✓	C.G. Clyde C.E. Israelsen W.J. Grenney	05-27-82	Federal Highway Admin.			
A Methodology for Estimating Embankment Damage Due to Flood Overtopping	Fred Kiefer C. E. Israelsen C. G. Clyde L. R. Anderson	06-23-82	Federal Highway Admin.			X
Calibration of a 48 inch sonic meter.	J. P. Tullis	07-12-82	Manning Environmental			X
Calibrate a 17.5 x 12.75 venturi meter. - Fairbanks Morse -Pump Division	J. P. Tullis	09-08-82	Fairbanks Morse Pump Division		X	
In-Situ Treatment Techniques Applicable to Large Quantities of Hazardous Waste Contaminated Soils	D. L. Sorensen Ron Sims Jerome Jurinak Dean Adams Judy Sims	September 16, 1982	JRB Associates		X	
Water Quality Assessment of the Proposed Gila River Reservoir	Jay J. Messer	October 06, 1982	BIOWEST (Tom Twedt)		X	
Evaluation of Systems to Accelerate Stabilization of Waste Piles or Deposits	R. Dupont J. Sims R. Sims L. Anderson C. Duffy	October 19, 1982	JRB Associates			X
Numerical and Physical Modeling of Two-phase Transients	J. Paul Tullis	October 22, 1982	NSF	X		
A Methodology for Balancing Considerations of economical energy Production & environmental quality at potential lowhead Hydroelectric site.	R. Narayanan Dean T. Larson	November 12, 1982	The Charles A. Lindbergh Fund, Inc.			X
Purchase of a Measurionics LSM-111tm system which will reduce time required for some data material by 10,000 times	F. Haws CE Israelsen J. Fletcher	December 14, 1982	NSF Eng. Equip. Pur.	X		

Table 10. Continued.

Proposal Title	Personnel	SUBMITTED		Pending	Funded	Rejected
		Date	Agency			
Engineering Research Equipment	AJ Seierstad	December 14, 1982	NSF	X		
Hydraulic Modeling Services Related to Hydropower Facilities at Sardis and Grendada Dams	CG Clyde <i>J.P. Tullis</i>	December 22, 1982	CH2M Hill			X
Development of Mathematical pro- gramming software for VAX Com- puter system.	Trevor Hughes Mac McKee Kim Marshall	January 14, 1983	Vice-President			X
Processes of Hydrogeologic and Agricultural Salt Loading in the Upper Colorado Basin	Chris Duffy	January 14, 1983	Vice-President			X
Harvesting Allelopathic Chemicals from Wastewater lagoons for Algal Species Control	Jay J. Messer	January 14, 1983	Vice-President			X
Nitrogen Relationships in Anaerobic Digestion	Ryan Dupont	January 14, 1983	Vice-President		X	
Model Study of IPP Circulating Water Pumps	J. Paul Tullis	January 31, 1983	Bingham-Willamette Company		X	
Stochastic (Time Series) Solution to the Convection-Dispersion Equation for Interpretation of Isotope and Geochemical Fluctuations in Groundwater	Chris Duffy	March 10, 1983	U.S. Dept. of Energy			X
Pike Island Hydroelectric Project Hydraulic Model Studies	J. Paul Tullis <i>Calvin Clyde</i>	March 23, 1983	Daverman Assoc. NY	X		
Circulation Water Pump Structure Model Study South Texas Project	J. P. Tullis	April 1983	Bechtel Corp.	X		
Evaluation of High Loading Rates and Assimilation Capacities for Land Treatment of Hazardous Wastes	<i>R. C. Sims</i> <del>B. L. Sorensen</del>	April 8, 1983	U.S. EPA		X	
Evaluation of Volatilization of Hazardous Constituents at Hazard- ous Waste Land Treatment Sites	R. R. DuPont	April 1983	US. EPA		X	
Control of Algae in Reservoirs	Jay J. Messer	May 1983	AWWA Research Foundation			X
Some Preventive Measures for Land Slides in Utah	Abdollah Jenab Calvin G. Clyde Loren Anderson	June 1983	Dept. of Transportation and Utah Geological & Mineral Survey	X		
Water as a Source of Cooperation or Conflict in the Middle East	Abdollah Jenab Bruce Anderson Alvin Bishop Wayne Criddle Douglas James Manouchehr Paydar Dean F. Peterson Paul Riley	June 1983	Virginia Contracting			X

Table 10. Continued.

Proposal Title	Personnel	SUBMITTED		Pending	Funded	Rejected
		Date	Agency			
Village Water Supply Planning Methodology	Trevor C. Hughes Mohammed Al-Eryani Mac McKee	June 1983	The World Bank	X		
Abandoned Wells as a Source of Groundwater Contamination in the Upper Colorado River Basin	C. Earl Israelsen Eugene Israelsen	May 1983	USBR (OWRT)			X
Regional Ground Water-Surface Water Management	Calvin Clyde James DeCook Gilbert Cochran Johannes DeVries Hubert Morel-Seytoux	June 1983	The Regents of Univ. of California			X
Social, Institution and Community Factors Affecting Implementation of Residential Water Conservation Policy and Programs: Policy Guidelines.	Gary Madsen Bryan Dixon Richard Krannich <i>Ryan Dupont</i> <i>Judy Sims</i> <i>L. D. James</i>	May 1983	USBR (OWRT)			X
Analysis of Water Conservation Efforts and Their Achievements in Four Urban Cities	Dennis Thompson (BYU)	May 1983	USBR (OWRT)			X
Increasing Arid Land Productivity through Water Catchment and Computerized Trickle Irrigation to Increase water use efficiency & Conservation	Darrell Weber Ron Walser (BYU)	May 1983	USBR (OWRT)			X
Integrated Conjunctive Water Resources Management of the Great Salt Lake Basin for Lake Water Level Control	L D. James Abe Jenab Calvin Clyde Jay Bagley Paul Riley Daniel Hoggan Ed Fisk Frank Haws James McCalpin	May 1983	Div. Water Res.			X
Aquifer Recharging in Utah	Clair Batty abe Jenab Calvin Clyde Chris Duffy Ed Fisk	July 1983		X		
Water Reclamation & Conservation in the Southwestern US: Policy Alternatives for Technology Adoption	Robert Lansfrod NM Ron Cummings NM Shaul Ben-David NM Helen Ingram U of A Jack Keller USU Bob Hill USU Ralph Young U of N	May 1983	USBR			X
Economic Evaluation of Conservation Programs for Municipal Water Supply Systems	Rangesan Narayanan Trevor C. Hughes A. Bruce Bishop Dean T. Larson Mac McKee	July 1983	USBR		X	

Table 10. Continued.

Proposal Title	Personnel	SUBMITTED		Pending	Funded	Rejected
		Date	Agency			
Hydrogeologic and Agricultural Salt Loading in Streams of the Upper Colorado River Basin: Model Development	Christopher Duffy Jerome Jurinak Jay J. Messer	July 1983	USBR			X
Strategies for the Conjunctive Management of Ground & Surface Water	Upmanu Lall	August 1983	USBR		X	
Detection of Cloud seeding Signatures using Automated Detection and Treatment Methods	Jeff Hill Duard Woffinden	September 1983	NSF		X	
Development of International Program for Water Resources System Planning & Operation	David S. Bowles L. Douglas James J. Paul Riley	9-15-83	USU Office of International Programs and Studies		X	
A Model Study of the Proposed Power Plant at the Hannibal Locks and Dam, Ohio River	J. Paul Tullis	8-83	EBESCO Services Inc. SEAWARD Construction Company, Inc.			
Circulation Water Pump Structure Model Study South Texas Project	J. Paul Tullis	5-83	BECHTEL ENERGY CORP.			
Optimization Study of Irrigation Efficiency & Salt-Ecosystem management in a drainage basin using remote sensing data acquisition, transmission analysis system	Abe Jenab	9-83	US Geological & Mineral Survey Div. of Water Resources (SLC)			
Innovative Concepts in the Application of Anaerobic Digestion for Energy Production: Phase Separation Using Rotating Biological Contactors	Ryan Dupont Darwin Sorensen	9-29-83	Solar Energy Research Inst. (Go			
Irrigation Projects, Income Distribution, and Rural Poverty	Rangesan Dean Peterson Dean Larson		Ford Foundation			
The Effects of Hazardous Waste-Site Contaminants on Soil and Aquatic Microbial Processes	Dean Adams Darwin Sorensen Fred Post	12/14/83	EPA (Corvallis)			
Computer Funds for Unfunded Research	Christopher Duffy	12/16/83	Vice President for Research	X		
Flood Control Investigations in the State of Utah (including the Great Salt Lake and the Sevier Lake Drainage Basins)	Calvin G. Clyde LDJ, TCH, CEI, AJ, DHH, JPR, DSB, FWH, EKI, RHH, JEF	12/16/83	Corps of Engineers			
Bear River Basin Study	Messer, Sorensen Grenney, & Adams	12/05/83	Division of Water Resources	X		



Table 10. Continued.

Proposal Title	Personnel	SUBMITTED		Pending	Funded	Rejected
		Date	Agency			
A Study on the Effects of Canal Losses on Groundwater and Stream Salinity: Upper Colorado Basin	Duffy	1/06/84	Vice President for Research (FRG)	X		
Virus Removal and Inactivation in Slow Rate Sand Filters	Sorensen Barnett	1/06/84	Vice President for Research (FRG)	X		
Cooperative Research on the Determination of Acid Formation Potential in Mineral Mine Spoils	Sorensen	1/16/84	Forestry Sciences Lab (campus)	X		
Design and Testing of a Self-Cleaning Filtered Diversion Device	Haws, EKI & CEI	1/16/84	Utah Power & Light			X
Uncertainty Analysis Applied to River Water Quality Modeling	Bowles	1/20/84	Vice President for Research	X		
Carcinogenic, Mutagenic, and Teratogenic Risks Associated with the Land Application of Municipal Sewage and Sludge	Sims, R. C. and R. P. Sharma	10/1983	EPA	X		
Forecasting the Summer Peak Water Surface Elevations of the Great Salt Lake	J. Paul Riley LD James and George Chadwick	2/7/84	National Weather Service		X	
Analysis and Design of a National Center for Water Resources Research and a National Water Information Clearinghouse	Gordon Chesters L. Douglas James Bishop, Hiibner	2/16/84	Council on Env. Quality (CEQ)			X
Pakistan Irrigation System Management (I)	Bowles	12/10/83	USAID			X
Pakistan Irrigation Systems Management (II)	Bowles & OSU	2/25/84	USAID			X
Overcoming Problems of Small Private Water Companies in Maintaining Safe, Dependable, and Cost Effective Drinking Water Service	Bagley, Hoggan and Haws	11/1983	Community Impact Board		X	
Utah Water Literacy Project	DR Dausg and CE Israelsen	3/1984	Division of Water Resources		X	
Debris Slide Initiation Due to Snowmelt in Mountain Terrain	Roland Jeppson Loren Anderson	1/19/84	NSF	X		
Economic Valuation of Aquatic Ecosystems	John Keith, RN, Ken Lyon, McKee ABB, WJG	4/6/84	EPA			X
Statement of Qualifications	Ryan Dupont	4/16/84	CH <sub>2</sub> M-Hill & U. S. Air Force	X		
Preston City Drainage Project	Abe Jenab	4/19/84	City of Preston, ID	X		
The Effects of Hazardous Waste-Site Contaminants on Soil and Aquatic Microbial Processes	Dean Adams, DLS, FJP	4/26/84	EPA	X		

Table 10. Continued.

Proposal Title	Personnel	SUBMITTED		Pending	Funded	Rejected
		Date	Agency			
A Feasibility Study of West Valley City Drainage Project	S. A. Jenab	5/14/84	West Valley City	X		
Role of Salt Gradient Solar Ponds in Reclaiming Irrigated Lands with High Saline Water Tables	J. Clair Batty J. Paul Riley	5/11/84	USAID	X		
Potential for Wind Power Combined with Supplemental Animal Power in Village Level Agriculture	Rajesh Dave	5/11/84	USAID			X
Innovative Methods for Treatment of Hazardous Aqueous Waste Streams	V. Dean Adams	4/30/84	EPA			X
The Effects of Hazardous Waste-Site Contaminants on Soil and Aquatic Microbial Processes	V. Dean Adams	5/24/84	EPA	X		
Environmental Monitoring and Evaluation of Calcium Magnesium Acetate (CMA)	R. Ryan Dupont	5/24/84	NCHRP			X
Quantification of the Aquatic Effects of Acid Precipitation on Lakes and Flowing Waters in the United States	Jay J. Messer	6/22/84	USEPA	X		
HARZA collaboration on an India Proposal	D. S. Bowles L. D. James		AID	X		
Instantaneous Determination of Water-Cement Ratio in Fresh Concrete	C. Earl Israelsen	6/25/84	TRB			X
Hydrologic Engineering Center Assignment	Daniel H. Hoggan	6/27/84	HEC-Dept. of Army Corps of Engineers		X	
Reducing Salinity in River Systems through Use of Benefit Enhancing Technologies	J.C. Batty J.M. Bagley W. T. Helm Mansour Sepehr	6/25/84	Preliminary Proposal			
Waterlogging and Salinity Hazards to the Burg El Arab Olive Groves and Its Environs	C. G. Clyde Ismail M. El Ramly	7/84	NSF	X		
The Effect of Reclamation of New Higher Land on the Adjacent Old Agricultural Land in Upper Egypt West of Samalut	C. G. Clyde K. Hefny	7/84	NSF	X		
Attenuation and Ion Exchange Characteristics-Laboratory Testing of Sample Low Rank Coal Waste Disposal Site Soils to Characterize their Capacity to Attenuate and Ion Exchange Inorganics	Lynn Dudley Jerome Jurinak Joan McLean	7/30/84	U.S. Dept. of Energy	X		
Stochastic Interpolation of Precipitation Data from Multiple Sensors	David S. Bowles C. J. Duffy W. F. Krajewski	7/13/84	NSF	X		

Table 10. Continued.

Proposal Title	Personnel	SUBMITTED		Agency	Pending	Funded	Rejected
		Date					
Low-Cost Transportation Systems Management (TSM) Projects--Simplified Procedures for Evaluation, Phase II	C. Earl Israelsen R. Kent Wood F. W. Haws R. S. Russon B. D. Warnick	9/24/84		Transportation Research Board			X
Managing the Water Resources of the Senegal River Basin	J. Paul Riley John E. Keith David S. Bowles Jay C. Andersen	83		Fed. Technol. Applications for less-devel. countries		X	
Evaluation of High Loading Rates and Assimilation Capacities for Land Treatment of Hazardous Wastes	Ronald C. Sims Judith Sims Darwin L. Sorensen Joan E. McLean	85		Federal Office of Water		X	
Carcinogenic, Mutagenic, and Teratogenic Risks Associated with the Land Application of Municipal Sewage and Sludge	Ronald C. Sims Judith Sims William F. Campbell Alberta J. Seierstad R. P. Sharma Dean V. Adams Ronald V. Canfield Joan E. McLean Raymond W. Miller	84		Fed. Water Poll. Control--Technical Training Grants		X	
Role of Salt Gradient Solar Ponds In Reclaiming Irrigated Lands With High Saline Water Tables	J. Clair Batty J. Paul Riley	84		Fed. Agency for International Dev.			X
Innovative Concepts in the Application of Anaerobic Digestion for Energy Produc: Phase Separation using Rotating Biological Contract	R. Ryan Dupont Darwin L. Sorensen	84		Private-Solar Energy Research Institute			X
Design and Testing of a Self-Cleaning Filtered Diversion Device	Frank W. Haws C. Earl Israelsen Eugene K. Israelsen	84		Private-Utah Power and Light			X
Engineering Center for Water and Hazardous Wastes Research	L. Douglas James Ronald C. Sims	85		Private-Oklahoma State University	X		
Development of General Purpose Culvert Design Computer Program	Ronald W. Jeppson	84		Federal Department			X
Air-Water-Land Information (AWL INFO) Engineering Research Center	J. Clair Batty Glen E. Stringham J. Paul Riley Martell J. Gee Ronald L. Thurgood	84		NSF			X
Water Resources Systems Planning and Management	L. Douglas James J. Paul Riley David S. Bowles	85		Private--Harza Engineering Co.	X		
Economic Valuation of Aquatic Ecosystems	John E. Keith Rangesan Narayanan	84		Federal Water Poll. Control-Research Dev. and Demo Grants			X

Table 10. Continued.

Proposal Title	Personnel	SUBMITTED		Pending	Funded	Rejected
		Date	Agency			
Institutional and Community Factors Affecting Implementation of Residential Water Conservation Policy and Programs During Acute and Long-Term Supply Limitations	Richard S. Krannich Gary E. Madsen Brian L. Pitcher L. Douglas James	4/15/85	U.S. Geological Survey			X
Techniques for the Immobilization of Metals Associated with Industrial Wastes in Land Treatment Systems	Joan McLean Judy Sims Ronald Sims	4/15/85	U.S. Geological Survey	X		
Concepts of Improving Operation of Existing Complex Irrigation Systems	Trevor C. Hughes Wynn Walker Bruce Bishop	4/15/85	U.S. Geological Survey			X
Hydrogeological and agricultural salt loading to streams of the Upper Colorado River Basin: Model Development and verification	C. J. Duffy J. J. Jurninak Donald Suarez	4/15/85	U.S. Geological Survey			X
Groundwater contamination through abandoned wells in the Upper Colorado River Basin	C. Earl Israelsen E. K. Israelsen	4/15/85	U.S. Geological Survey			X
Coordinating Flood Mitigation Policies and Programs with those for Protecting Instream Flow Valves	Jay M. Bagley William T. Helm	4/15/85	U.S. Geological Survey			X
Feasibility of Incorporating Salt Gradient Solar Pond Energy, Aquaculture and Mineral Extraction Technologies to Control Point Sources of Salinity in River Systems	J. Paul Riley Jay M. Bagley J. Clair Batty W. T. Helm M. Sepehr	4/15/85	U.S. Geological Survey			X
Flood-Sediment Model for Steep Mountain Watersheds	L. Douglas James D. H. Hoggan D. S. Bowles R. Hawkins	4/15/85	U.S. Geological Survey			X
Overtopping Damage Minimization Part I & II & III	F. W. Kiefer C. E. Israelsen L. R. Anderson C. G. Clyde	4/16/85	Fed. Highway Admin. Washington, D.C.			
A Comparative Study of Response to Flood and Drought Risks and Analysis of Costs and Benefits	T.C. Hughes D. S. Bowles A. B. Bishop	4/12/85	U.S. Geological Survey			X
Development of a Prototype Expert System for the Protection of Groundwater Resources from Hazardous Wastes	W. J. Grenney R. Sims	4/05/85	U.S. Geological Survey			X
Multispectral Remote Sensing and Classification Modeling of Areas Susceptible to Mass Wasting	L. R. Anderson R. W. Gunderson M. A. Jadkowski	4/15/85	U.S. Geological Survey			X

Table 10. Continued.

Proposal Title	Personnel	Date	SUBMITTED Agency	Pending	Funded	Rejected
Research on Processes Contributing to Mass Wasting and Downslope Hazards	L. R. Andersen L. Douglas James R. W. Jeppson Jeff Keaton David S. Bowles	5/13/85	<del>USGS</del> USGMS		X	
Techniques for the Immobilization of Metals Associated with Industrial Wastes in Land Treatment Systems	Ronald C. Sims J. McLean J. Sims	4/9/85	EPA		X	
JER Proposals	James	4/5/85	WRRIP Funds		X	
Interstate water transfers: impediments & impacts in the Colorado basin, phase I.	Jay M. Bagley	4/30/85	CWIC	X		
Landslide processes in Utah and Monitoring of landslides and debris flows	L. D. James	4/85	UGMS		X	
Evaluation of Loading Rates and Assimilation Capacities for Land Treatment of Hazardous Wastes	R.C. Sims J.L. Sims J.E. McLean R.R. Dupont D.H. Falkenberg	6/13/85	EPA	X		
CH2M Hill, Boise, Idaho	J.P. Tullis	6/85	CH2M Hill	X		
Proposal for Field Sampling and Analysis Protocol for Air Emission Release Rate Monitoring from a Hazardous Waste Land Treatment Demonstration Facility	R. R. Dupont	7/85	USEPA	X		
An Investigation of Phosphorus Sources and Controls for Water Resources Development in the Bear River Basin	D. L. Sorensen W. J. Grenney	7/15/85	State of Utah, DNR, DWR		X	
The Side Effects of the Aswan High Dam, Egypt	C. G. Clyde D. W. James	9/19/85	NSF/George Washington Univ.	X		
Characterization of Basin Structure and its Relation to Subsurface Generation of Streamflow: Upper Sheep Creek Watershed	C. J. Duffy	10/16/85	ARS-Boise		X	
FY 1986 Utah Water Resources Research Program	L.D. James C.J. Duffy etc.	01/03/86	USGS		X	
Performance of Land Treatment Demonstrations for Pentachlorophenol and Creosote Wastes.....	R.C. Sims	12/16/85	U.S. Pollution Control Inc.	X		
Support Studies for Land Treatment Decision-Model Development/Verification and Input Data Generation	W.J. Grenney R.C. Sims D.L. Sorensen R.R. Dupont W.J. Doucette	02/03/86	U.S. EPA	X		

Table 10. Continued.

Proposal Title	Personnel	SUBMITTED		Pending	Funded	Rejected
		Date	Agency			
Center of Excellence for Advanced Studies in Hydrologic Science	L. D. James	02/28/86	USU(Dean & Provost)	X		
Prioritizing Eligible Need and Available Funding in the Operation of Multiple Federal/Non-Federal Financing Programs	J.M. Bagley F.W. Haws	02/27/86	USGS	X		
The Effect of Present Water Quality Management Practices on Future Groundwater Quality in Heber Valley	C.G. Clyde	02/27/86	USGS	X		
Evaluation and Modeling of Volatile Organic Vapor Transport in the Unsaturated Zone for Groundwater Quality Protection	R.R. Dupont	02/27/86	USGS	X		
Deep Aquifer Contamination of Shallow Groundwater	C.E. Israelsen	02/27/86	USGS	X		
Soil Phase Photodegradation of Toxic Organics at Contaminated Disposal Sites for Soil Renovation and Groundwater Quality Protection	W. Moore R. Dupont	02/27/86	USGS	X		
Computer-Assisted Operation of Irrigation Delivery Systems	W.R. Walker T.C. Hughes	02/28/86	USGS	X		
Improving Irrigation Efficiency with Real-Time Data Management-equipment, operations and economics	G. Stringham A.B. Bishop P. Wheeler	02/28/86	USGS	X		
Groundwater Investigation of SO <sub>4</sub> <sup>=</sup> Diffusion from a cretaceous Shale Hillslope: Upper Colorado River Basin	C. J. Duffy J. McCalpin	02/28/86	USGS	X		
Maximum Economics Water-Use Efficiency and Effects of Pricing Systems on Irrigation System Design and Operation	R. Allen R. Hill J. Andersen	02/28/86	USGS	X		
Bioassessment of Hazardous Waste Site Contaminant Effects in Soil and Aquatic Microbial Processes	D.L. Sorensen R.C. Sims F.J. Post	02/86	EPA	X		
Multiple Seismic Hazards Evaluation for Wasatch Front, UT	D.S. Bowles L.R. Anderson J. Keaton T.F. Glover	03/86	USGS			
Water Resources Studies-Phase I	D.S. Bowles T.C. Hughes W.J. Grenney	03/86	Ut.Div. Water Resources			
Nonparametric Assessment of Multivariate Serial Dependence and Non-Gaussian Simulation of Environmental Series	J.P. Riley R.V. Canfield	02/86	USGS			

Table 10. Continued.

Proposal Title	Personnel	SUBMITTED		Pending	Funded	Rejected
		Date	Agency			
A General Analysis System for Combining Forecast Models	J.P. Riley R.V. Canfield E.K. Israelsen	02/86	USGS	X		
Feasibility of Incorporating Aquaculture, Solar Pond Energy, and Mineral Extraction Technologies to Control Localized Sources of Salinity in River Systems	J.P. Riley J.M. Bagley J.C. Batty W.T. Helm M. Sepher	02/86	USGS			
Design of An Expert system for Partial-Area Hydrologic Mapping Using Remote Sensing Data	J.P. Riley R.W. Gunderson	02/86	USGS			

## 9. ADMINISTRATIVE RELATIONSHIPS

The UWRL administers a line item budget for water resources research, operates the research facility, and serves as the administrative center for the bulk of the contract water resources research from external sources to the University. The UCWRR extends a campus-wide umbrella for interfacing with the water resources research program of the Department of the Interior. The two units are run by a common administration. It is time to review whether continuation of this dual entity is desirable from the viewpoints of the USGS or the University. The original reasons for separation seem to be diminishing, and a double entity adds to the burden of program administration.

The UWRL/UCWRR reports to a university-wide committee of the Deans of the relevant colleges and other related program administrators (see Table 2). The Dean of Engineering has the leadership role for budgeting and reporting purposes. We should review how best to strengthen program visibility and participation campuswide and improve access to the program in the other colleges.

The Director has ready access to all levels of the university administration with the principal contact at the top level being the Vice President of Research. University administrators at all levels consider the program to be one of the strong points of the University. Currently, the University is looking for programs to build as centers of excellence, and water resources research has an important goal (see Part 3).

The entire time of the Director is spent in water resources administration, research, and teaching. Non-administrative commitments include two courses a year in hydrology and water resources planning in civil engineering, project leader on several research projects in these same general areas, and research direction given 12 graduate students.



## 10. INSTITUTIONAL COMMITMENT

Utah State University is strongly committed to excellence in water resources research. The support extends program planning, faculty hiring, and budgeting. For example, the State supports UWRL/UCWRR with a line item budget that currently approaches \$1,400,000 annually, approximately equally funded from a line item state appropriation and a dedicated percentage of mineral lease collections. During each budget cycle, the legislature estimates the mineral lease collections for the coming year and then appropriates the necessary supplemental funds to bring the combined amount to a desired total. That total increases with inflation and periodic specially assigned projects.

In the last two years, this division of state funds has become a problem because mineral lease collections have been dropping precipitously. At the end of FY 1986, it appears that the Laboratory will be hit with a shortfall exceeding \$100,000. Prospects are high for the same situation in 1987.

We are currently valiantly trying to make up the difference by obtaining supplemental funding. The University administration has been very supportive in helping to work out satisfactory arrangements.

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A-024 - F. J. Post and D. B. Porcella  
"Nitrogen Cycling as a Water Quality Factor in the Great Salt Lake"

A-025 - J. P. Riley, C. G. Clyde, and W. J. Grenney  
"Development of a Hydroquality Management Model of the Great Salt Lake--Phase II"

A-026 - L. S. Davis  
"Recreational, Environmental, and Economic Consequences of Alternative Development Programs for the Bear Lake Area"

A-027 - B. D. Gardner and K. S. Lyon  
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A-032 - A. B. Bishop  
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A-034 - D. S. Filip and D. B. George  
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"A Chemical Model of Heavy Metals in the Great Salt Lake"

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"Investigations of Virus Removal from Water with an Evaluation of a New Virus Detection Procedure"

A-042 - D. S. Bowles, T. C. Hughes, and F. W. Haws  
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A-044 - V. D. Adams, V. Lamarra, and D. B. George  
"Calcium Carbonate Precipitation in Streams as Controlled by Physical-Biological Reactions"

A-045 - J. J. Jurinak and R. J. Wagenet  
"Salt Release From Suspended Sediments: A Simulation Model"

A-046 - J. P. Riley, D. S. Bowles, and E. K. Israelsen  
"Management of the Hydrologic System in Areas Subject to Coal Mining Activities"

A-047 - J. E. Keith, J. M. Bagley, and J. C. Andersen  
"An Evaluation of Trade Offs Among Water Use, Air Quality, and Economic Costs in Power Plant Siting"

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A-050 - R. L. Little  
"Water Transfers from Agriculture to Industry: Two Utah Examples"

A-051 - J. J. Messer and V. D. Adams  
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- B-131 - J. E. Keith, A. B. Bishop, and R. Narayanan  
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- B-132 - R. Narayanan, A. B. Bishop, and M. McKee  
"Development of an Interactive Planning Methodology for Displaying Effects and Establishing Public Preference among Multi-objective Water Resource Plans"
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- B-141 - R. Narayanan and A. B. Bishop  
"Alternative Energy Development Options and the Impact on Water Resources and Salinity"
- B-143 - G. F. Gifford  
"Sorptivity--A Feasible Concept for Infiltration Estimation on Small Rangeland Watersheds"

B-145 - W. J. Grenney, T. C. Hughes, and A. B. Bishop  
"Optimization of Water Resources Systems Using Interactive Integer Programming Simulation Models"

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B-148 - L. S. Willardson, R. J. Hanks, and J. J. Jurinak  
"Impact of Water and Soils Having High Source-Sink Potentials on Water and Salinity Management Under Irrigation in the Upper Colorado River Basin"

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B-172 - D. S. Bowles, J. J. Jurinak, and J. P. Riley  
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B-185 - R. Narayanan, B. Biswas, and J. C. Andersen  
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B-189 - J. M. Bagley and D. T. Larson  
"Adapting Western Water Law to Accommodate Equitable Consideration of Instream Flow Uses"

B-204 - T. C. Hughes, A. B. Bishop, and H. H. Fullerton  
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B-210 - V. A. Lamarra, V. D. Adams, and A. J. Seierstad  
"The Evaluation of Heavy Metals and Potentially Carcinogenic Organics Released into Coal Mine and Oil Shale Accrual Waters"

B-214 - F. J. Post, J. J. Messer, and V. D. Adams  
"Effects of Complexation with Oil Shale Leachate on Heavy Metal Bioaccumulation"

C-6029 - W. H. Andrews and G. E. Madsen  
"The Effects of Early Planning on Improving Post Development Management in Multi-purpose Water Resource Development"

C-6279 - Jim Mulder, D. H. Hoggan, D. T. Larson  
"Integrating Water Resources and Land Use Planning"

C-7028 - H. H. Fullerton and Mac McKee  
"Water Resource Development and Ute Indian Self-Determination"

C-7106 - W. H. Andrews and G. E. Madsen  
"Application and Verification Test of the Western TECHCOM Taxonomy to an Existing Water Development Project: a Post-Facto Examination and Demonstration"

C-7161 - Jim Mulder, D. T. Larson, L. D. James  
"A Study of Interactions Among Different Levels of Analysis in Comprehensive River Basin Planning"

C-80129 - L. D. James, D. T. Larson, M. McKee  
"Index Construction for Conjunctive Water and Land Management: A Process Tested on a High Mountain Watershed"

C-80322 - C. E. Israelsen, J. C. Batty, D. B. George  
"Use of Saline Water in Energy Development"

WG-305 - V. A. Lamarra and V. Dean Adams  
"1981 Symposium on the Aquatic Resources Management of the Colorado River Ecosystem"

T-0021-UTAH - W. H. Andrews and L. D. James  
"Dissemination of Information on Dealing with Emergency Drought Conditions Among the Western States"

JER-007 - L. D. James and J. J. Messer  
"Utah's Five Year Water Resources Research Goals and Objectives"

JER-201 - C. J. Duffy and J. J. Jurinak  
"Modeling Relationships of Salt Transport from Irrigation and Weathering of Underlying Sediments: Price River Basin"

JER-202 - A. B. Bishop and R. Narayanan  
"Development of a Comprehensive Upper Colorado River Basin Model for Analyzing energy Development Impacts"

JER-203 - C. G. Clyde and L. S. Willardson  
"Field Evaluation of Groundwater Salinity Buildup from Irrigation of Saline Alluvium"

JER-204 - V. Dean Adams  
"Comparison of Direct Filtration and Conventional Water Treatment Systems to Remove Pollutants from Source Waters"

JER-205 - J. M. Bagley and F. W. Haws  
"Overcoming Problems of Small Private Water Companies in Maintaining Safe, Dependable, and Cost Effective Drinking Water Service"

JER-206 - G. E. Hill  
"Real-time Control and Data Acquisition Systems for Remotely Located Hydro-meteorological Devices and Sensors"

#### Projects Currently in Progress

JER-306 - R. C. Sims, J. E. McLean, J. L. Sims  
"Protection of Groundwater by Immobilization of Hazardous Metals Associated with Industrial Wastes in Land Systems"

JER-502 - G. E. Bingham, L. E. Hipps, E. K. Israelsen, J. C. Batty, and J.P. Riley  
"A Comprehensive Study of Water Cycling in the Great Salt Lake Basin: Hydrometeorology of the West Desert Area"

JER-503 - C. J. Duffy and J. McCalpin  
"A Conceptual Model of the Hydrogeology of Closed Desert Basins"

JER-504 - R. D. R. Parker, R. P. Sharma, and R. R. Dupont  
"Toxicity and Environmental Health Hazards of Petroleum Products in Wells Used for Drinking Water in the Intermountain West"

JER-505 - J. P. Dobrowolski, R. J. Hanks, and U. Shani  
"Soil Moisture Flux in Stabilized Vesicular Horizons"

JER-506 - W.J. Doucette, R. C. Sims, and R. Ryan Dupont  
"The Use of Structure-Activity Relationships as an Aid in Modeling the Subsurface Transport of Organic Contaminants"



## DEVELOPMENT OF HYDRAULIC METHODS FOR SOLUTION OF FLOOD FLOWS ON ALLUVIAL FANS

### Abstract

A relationship based on empirical data for defining energy loss was combined with equations of motion and continuity to characterize debris flows emerging from Utah mountain canyons, and a computer program was written to solve those equations as one tool needed to provide estimates of the hazard to property below.

#### Principal Investigator(s)

Roland W. Jeppson (PhD), Civil Engineering

#### Student Assistant(s)

Alfredo DeLeon (PhD), Civil Engineering  
Salvador Rodrigues (MS), Civil Engineering

The physical properties of flows that are heavily laden with debris are vastly different than those of water. The flow equations used for water are not applicable and, if used, result in gross error. Appropriate relationships to describe hydraulic behavior, specifically how the velocity and depth of flow related to geometry and volumetric flow rate, do not exist. This research has sought to fill this void with methods that are simple enough to apply in practice and yet adequately represent the behavior of real debris flows.

More specifically, the objectives are to: 1) characterize debris flows on the basis of hydraulic properties, 2) develop flow equations that adequately describe many, if not the majority of, debris flows, 3) solve these equations numerically in a computer program. The solutions will be for spatially varied but steady-state flows and for unsteady flows including the movement of the leading wave of the debris flow as it propagates over the water flow previously existing in the channel.

#### Research Project Accomplishments

Under the assumption that debris laden fluid is laminar, which is born out by observations of these flows, relatively simple relationships between flow quantities have been developed. These relationships are incorporated into Chezy's equation to define the gradient of the energy line. This definition of fluid friction losses in turn is used in the differential equation for spatially varied flow to provide a solution to steady-state flows. The same definition of fluid friction losses is used in the partial differential equations of motion and continuity, commonly referred to as the Saint-Venant equations, to provide a numerical solution of unsteady flows. Our implicit scheme is used to solve the difference equations resulting from the Saint-Venant equations.

Computer solutions to both steady-state and unsteady flow conditions have been ob-

tained to see how close they duplicated the limited debris flow for which data are available. The agreement is good.

#### Application of Research Results

The solution methodology developed provides a means of predicting the depths and velocity of debris flows over deltas downstream from mountain canyons such as those along the Wasatch Front, for any volumetric debris flow. This predictive capability allows more rational estimates of damages that are likely to occur and permits evaluation of the effectiveness of various reasons for mitigation or prevention of economic loss due to flood damage.

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Office of Water Research and Technology,  
Agreement No. A-053, 14-34-0001-1147, 10/01/80  
- 03/31/83, Research Completed, FCCSET category: II-E.

## Publications

- DeLeon, A. A., and R. W. Jeppson. 1982. Hydraulics and numerical solutions of steady-state but spatially varied debris flow. UWRL/H-82/03, Utah State University, Logan, Utah.
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# ASPEN TO CONIFER SUCCESSION: A PROCESS AGGRAVATING THE SALT POLLUTION PROBLEM IN THE COLORADO RIVER BASIN

## Abstract

Forest transpiration and interception patterns for aspen, spruce, and fir were determined for application in a hydrologic model to estimate the runoff reduction to be expected from the aspen to conifer succession currently occurring on the high mountain watersheds within the Colorado River Basin and to determine what level of effort to put into forest management practices to reverse the trend.

### Principal Investigator(s)

Gerald F. Gifford (PhD), Watershed Science

### Support Personnel

Richard Jaynes (MS), Watershed Science

### Student Assistant(s)

William Humphries (MS), Watershed Science	Tom Metzger (BS), Watershed Science
John Whitehead (BS), Watershed Science	Kevin Higgenbottom (BS), Watershed Science
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Rex Hamner (BS), Range Watershed	
John Madany, Range Watershed	

The ecological progression in high mountain watersheds in the Upper Colorado River Basin is from aspen to conifer forest. The succession reduces runoff volumes and hence the water available to downstream users. The objectives of this project are to determine 1) the magnitude of the runoff reduction as an aspen watershed proceeds to conifer climax, and 2) the extent to which this shift can be halted or reversed by reasonable management practices. Reasonable management practices include controlled burning and altered timber harvesting schemes.

Aspen forests are generally subclimax communities in the Rocky Mountain region. Mature aspen forests are naturally replaced by evergreen conifers unless some form of catastrophic disturbance (i.e., fire, disease, or clearcutting) occurs. When the overstory canopy of an aspen forest is removed, aspen sprout from the roots, and the aspen stand perpetuates itself. As man has prevented natural fires and clearcutting has been minimized, many areas once dominated by aspen have now become coniferous forests.

The aspen to conifer succession significantly increases total seasonal evapotranspiration and hence reduces water yield. The effect is already being felt since the aspen to conifer succession is presently quite advanced on many aspen acreages. Besides decreasing natural water yields, increasing conifer acreage may also significantly reduce the gain in water yields achievable through snow augmentation by cloud seeding. Runoff volumes from forest areas depend on the interaction between the seasonal consumptive use pattern for the vegetative type and the influence of vegetative type on snowpack behavior. Water yield reductions attributable to the aspen to conifer conversion can, therefore, be related to transpiration and canopy interception changes.

### Research Project Accomplishments

Based on field measurements of aspen and conifer transpiration patterns over the growing season, the model ASPCON was used to predict water loss from aspen, spruce, and fir forests. The hydrologic effects of aspen to conifer succession are modeled by using a series of moisture storage compartments connected by transfer equations. As moisture enters and interacts with a watershed, a certain amount is lost to the atmosphere via

evapotranspiration, while the remainder may become streamflow or percolate deep into the soil.

ASPCON is a deterministic, lumped-parameter model in which the watershed is treated as a single series moisture storage "tank." Model coefficients represent average watershed characteristics. The model calculates weekly water budgets throughout the water-year (October 1 to September 30). Input

includes only precipitation and average weekly air temperature. The model was calibrated for an "average" water-year on the West Branch Chicken Creek Watershed, Davis County Experimental Watershed. The purpose of the calibration was to develop a reasonable point of reference against which hydrologic changes attributable to vegetation changes may be estimated. The ASPCON model was then modified as needed to reflect the data acquired on plant activity patterns and community crop coefficients for spruce, aspen, and fir forests.

Using these new coefficients on the timing and rates of transpiration, the model predicts 18.5 cm (7.3 in.) net loss of moisture available for streamflow when spruce replace aspen, and a loss of 7.1 cm (2.8 in.) when fir forests cover the watershed (Figure 1). If all 3.3 million acres of aspen within the Colorado River system were replaced by conifer, this translates into 2,467 million and 987 million cubic meters (2.0 and 0.8 million acre-feet) of water, respectively.

#### Application of Research Results

The ability to quantify the water-use difference associated with aspen to conifer succession permits forest managers to estimate the effects on water yields associated with forest management practices that favor either aspen or conifer. Planners responsible for overall water management will have better information for determining what level of effort to put into managing vegetation on high mountain watersheds.

#### Publications

Gifford, G. F., W. Humphries, and R. A. Jaynes. 1983. Aspen to conifer succession: a process aggravating the salt pollution problem in the Colorado River Basin. UWRL/H-83/01, Utah State University, Logan, Utah.

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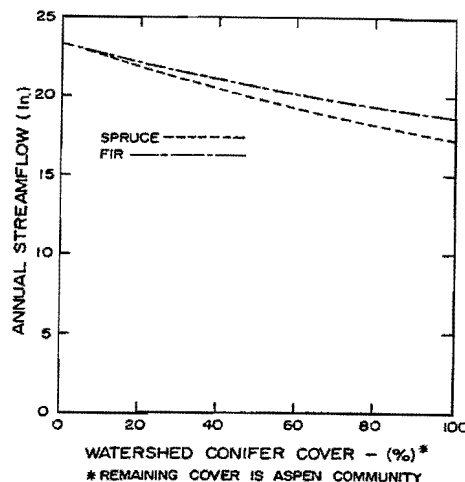


Figure 1. Water yield as a function of vegetation cover (aspen versus conifer) on the Chicken Creek Watershed.

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10/01/78 - 12/31/81, Research Completed,  
FCCSET Category: II-B,D

THE RESPONSE OF FRESHWATER ECOSYSTEMS TO ALLOCHTHONOUS  
ORGANIC MATERIAL

Abstract

The effects of two crude oils, should they be chronically loaded or suddenly spilled, on two freshwater (one hard and one soft) lake ecosystems are being examined and show that nutrient immobilization is a greater factor than toxicity in affecting lake water quality.

Principal Investigator(s)

V. Dean Adams (PhD), Organic Chemistry  
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Student Assistant(s)

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Oil deposits in the Wyoming Overthrust Belt are likely to be heavily exploited in the future. Oilfield development can impact freshwater ecosystems either by chronic low level loading or suddenly by major accidental spills. In order to be better prepared for both possibilities, we need a better understanding of how both would affect freshwater lake ecosystems. While much research has been conducted on the effects and fate of oil in marine systems, little work has been done on freshwater systems. Such studies need to begin from base line data on the effects which crude oil has on the major system components (e.g. autotrophs, heterotrophs, and decomposers) as well as effects on the structure and function of the ecosystem as a whole. The degradation of the oil when exposed to the natural flora and fauna of fresh water also needs to be explored.

Research Project Accomplishments

The research was conducted using two crude oils, a local light weight crude from the Wyoming Overthrust Belt and a more viscous standard South Louisiana Crude used in many marine studies. Two study sites were used. Bear Lake, Utah-Idaho, is in a limestone drainage high in calcium, magnesium, and carbonate concentrations, and hence a hard water lake. New Fork Lake, in a granitic watershed in the Wind River Mountain Range of western Wyoming, is a soft water lake. The use of dissimilar lakes and oil types broadens applicability of the results to more situations of oil spillage into freshwater lake systems.

The chemical compositions of Bear and New Fork Lakes were determined and artificial media were made to simulate each of the lake waters. These media were used in a bottle bioassay test to determine effects of

two crude oils on the growth of Selenastrum capricornutum. Increasing concentrations of the oils increasingly inhibited growth rates and maximum standing crops of the alga. For a given concentration, the Wyoming crude was more deleterious to algae growth than South Louisiana crude oil.

Extensive experimentation was conducted on the effects of crude oil on an integrated aquatic ecosystem developed in three-phase (gas, aqueous, and sediment) microcosm systems which simulated conditions in the lakes. The microcosms contained sediments collected from the study lakes (Bear and New Fork), an inoculum of naturally occurring organisms from the lakes, and the artificial media simulating the lake water. Notable responses of the microcosm ecosystem to oil impaction included an increased oxygen demand by the biological community; nutrient (spe-

cifically nitrogen and phosphorus) immobilization; a reduction in plant biomass accumulation; and an overall heterotrophically dominated ecosystem. Nutrient immobilization, rather than toxic effects of oil on plants, apparently was the primary factor leading to the long-term imbalance between autotrophs and heterotrophs following oil impaction.

In situ decomposition experiments were also conducted to determine the effects of crude oil on aquatic vascular plant litter decomposition. Studies were performed in Bear and New Fork lakes using two plant species, one coated with one of the crude oils and the other left uncoated. In general, crude oil reduced the rate and extent of litter decomposition, but the activity of the decomposer communities associated with oiled litter was greater than, or equal to, that of uncoated litter.

Increased rates of oxygen utilization were identified as a potentially primary deleterious effect of oil pollution. Crude oil did not affect the nutrient content of plant litter at any stage of litter

decomposition, but the rate of nutrient loss from the litter was reduced by the reduction in the rate of decomposition. Of the nitrogen and phosphorus lost from plant litter, much less was actually released to ambient water in inorganic form from oiled litter than from uncoated litter. Nitrogen limitation to decomposers may have been the primary factor reducing the rate of oiled litter decomposition.

#### Application of Research Results

The research provides insight into the effects of petroleum pollution on freshwater ecosystems. Guidelines for regulating petroleum drilling operations can only be based on risks to natural freshwater ecosystems when descriptive information on those risks is available.

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Agreement No. B-187, 14-34-0001-0253, 10/01/  
79 - 09/30/82, Research Completed, FCCSET  
Category: II-A,B,C.

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A CONCEPTUAL MODEL OF THE HYDROGEOLOGY OF  
CLOSED DESERT BASINS

Abstract

A model of freshwater movement above the brine interface in closed desert basins is adding understanding of groundwater availability and desert climate for more effective water resources management.

Principal Investigators

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Support Personnel

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Student Assistants

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The western half of the State of Utah and almost the entire State of Nevada lie in a region characterized by internal drainage known as the Great Basin. Hydrologically, the most striking feature of this region is that no surface or subsurface flow leaves these basins. All the precipitation is returned to the atmosphere by evaporation or transpiration. Most of the available fresh water is stored underground. Historically, water resource development has been limited, and as a result, little is known about the hydrologic processes and patterns of circulation of ground and surface water. In recent years, the need to learn more has been emphasized by the information needed for 1) safe siting of waste repositories, 2) lake level control during wet periods of years, 3) siting possibilities for a major accelerator for nuclear research, 4) various military operations, and 5) agricultural development.

In order to better assess the potential and sensitivity of water resource development in this region, there is a need for better scientific understanding of the existing surface and subsurface hydrologic and meteorologic conditions. Pilot Valley in west central Utah has been chosen as a study site to begin this research to develop a conceptual/mathematical model of the existing groundwater-surface water circulation patterns and how they are affected by meteorological and climatic trends in precipitation and evapotranspiration.

Research Project Accomplishments

The first phase of the study has involved field reconnaissance and the installation of several piezometer batteries along the eastern flank of the Pilot range. Geophysical studies are underway to locate and map the freshwater-brine interface which occurs in the subsurface along the margin of the basin. The location of this interface is felt to be extremely important to groundwater circulation (recharge and discharge patterns) in the basin, as evidenced by the line of freshwater springs which are forced to the surface along the dense brine interface. The situation is apparently similar to the salt water-freshwater wedge which develops in coastal aquifers.

Application of Research Results

The conceptual model developed in this study will provide a framework for understanding patterns in the processes within the hydrologic cycle unique to undrained desert basins. Example issues of applied interest include 1) evaporation of saline waters, 2) desert floor climate and humidity, 3) groundwater development along basin margins, and 4) the contribution of groundwater to stage changes in desert lakes.

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U.S. Geological Survey  
05/01/85 - 07/01/87  
Research in Progress

A COMPREHENSIVE STUDY OF WATER CYCLING IN THE  
GREAT SALT LAKE BASIN: HYDROMETEOROLOGY OF THE  
WEST DESERT AREA

Abstract

The hydrology and meteorology of the West Desert have not been well defined even though the desert plays an important role in determining the climate of the entire region including the heavily populated Wasatch Front. An evaporative potential model, developed by the researchers and calibrated with data acquired at specific desert locations, will permit a better understanding of cloud, fog, and precipitation patterns that impact military training procedures, transportation links, lake levels, and agriculture.

Principal Investigators

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Lawrence E. Hipps (PhD), Soil Science and Biometeorology  
Eugene K. Israelsen (MS), Civil Engineering  
J. Clair Batty (PhD), Mechanical Engineering  
J. Paul Riley (PhD), Civil Engineering

Statement of Water Problem

Historically, the vast, desolate desert west of the Great Salt Lake has been of little interest for development except for military training and testing purposes. Consequently the hydrology and meteorology of the region have not been well defined. Very few data exist on surface temperatures, potential or actual evaporation rates, or atmospheric mixing parameters. It is becoming increasingly evident that the West Desert plays a major role in the climate of the heavily populated Wasatch Front. During winter, cold front winds create lake effect snow belts to the southeast of the lake. In summer, the desert may act as a solar collector to warm evaporation enhancing winds that pass over the Great Salt Lake, or if wet, the desert may suppress evaporation from the lake. When the Great Basin high pressure system is present, moisture from the West Desert region can spawn additional foggy or cloudy conditions in the Utah Test and Training Range of the U. S. Air Force. A relatively little known study of the Bonneville Salt Flats area concludes that relative humidities in both spring and summer of that region are much greater than one would expect in desert basins. If this condition extends over the Great Salt Lake western desert, calculations of the evaporative potential of the ponds proposed for lake level control may have been seriously overestimated.

The significance of humidity levels in the air can be shown from simple thermodynamic considerations. The movement of water from a surface into the lower atmosphere results from a difference between the water potential of the evaporating surface and that of the overlying air. Rising lake levels and the breaching of the causeway are changing the circulation, salinity, stratification, temperature and evaporation patterns of the Great Salt Lake. The lake may be further impacted in the future by construction of deep water dikes and high volume pumping. These changes will influence



not only operations of the mineral extraction industries, but also weather patterns along the Wasatch Front in an as yet unpredictable manner.

There are other closed basins experiencing changes in precipitation and weather patterns where the fundamental driving phenomena are also not well understood. For example, in the Harney Basin of Oregon, the Harney Lake and the adjacent Malheur Lake present an interesting parallel to the Great Salt Lake and the West Desert. Clearly, a comprehensive study of water cycling in closed basins is needed, and the hydrometeorology of the West Desert is the foundation element of such a study.

### Results and Benefits

This study is contributing scientific knowledge of basin-wide water cycle dynamics and providing much needed information for land, water, and salt use planning. A foundation of measured meteorological data (solar and net radiation, wind speed and direction, soil heat flux, Bowen ratio and atmospheric stability profiles at key locations in the West Desert) will allow determination of the Desert's evaporation potential. In turn, this information is fundamental to understanding the aerosol, water vapor and energy plumes which produce local climate patterns for the region. These results are essential beginning elements for a long range comprehensive study that will be used by the U. S. Air Force, State and Federal resource management agencies, the Utah Department of Transportation, and mineral extraction industries.

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USGS

May 1 1985 - November 30, 1987  
Research in progress

## SOIL MOISTURE FLUX IN STABILIZED VESICULAR HORIZONS

Abstract

This study will contribute to better scientific understanding of moisture flux through the crusted surface soil horizons found in desert basins throughout the west. The capability of quantifying moisture movement through these crusts can be used to enhance the rehabilitation of denuded areas and the protection of range watersheds.

Principal Investigators

James P. Dobrowolski (PhD), Watershed Science  
R. John Hanks (PhD), Soil Science and Biometeorology  
Uri Shani, Soil Science and Biometeorology

Statement of Water Problem

The Great Basin Physiographic Province is one of the largest, relatively uniform geomorphic, climatic and vegetation regions in the United States. The western half of the State of Utah and almost the entire State of Nevada are located within this province. Hydrologically unique, the region contains a number of topographically closed basins characterized by internal drainage. About 60 percent of the landscape has been formed from gently sloping loessial, alluvial, or lacustrine fill where pluvial lakes existed. Soils of these basins and basin margins are typically fine-textured Aridisols, easily eroded by surface water and wind. The arid to semi-arid climate restricts vegetation to a sparse, perennial shrub and grass mantle. Although some areas have been developed for agriculture, limited water supplies have restricted resource development to livestock production, recreation, and military testing operations. However, recently proposed nuclear waste repositories and study sites for nuclear physics experimentation may accelerate the development of this region. These activities, interacting with other anthropogenic and natural factors provide the potential for site disturbance with associated vegetation removal, accelerated soil loss, and excessive surface runoff. Recent rehabilitation efforts by U. S. government personnel on vast areas denuded by fire have met with limited success or complete failure. Rehabilitation failures (accelerated soil loss) may be due, in part, to the propensity of the native soil to form soil crusts and other structural impediments to infiltration and percolation, in the absence of vegetation. Surface sealing produced by raindrop impact on bare soil and algae crusts are typically found in stabilizing horizons containing non-interstitial macroscopic vesicles.

Given the potential for future development in Nevada and western Utah, clear scientific understanding of the interactive role that soil surface sealing and the underlying horizons play in the surface hydrology of the region is important for the protection of this fragile natural environment. Toward this purpose, this study would characterize structural surface sealing, microphytic crusting, and vesicular horizons to vertical water flux at selected site in the desert regions of central Nevada and western Utah. Determination of the hydraulic properties of these soil structures through in situ estimations may permit more precise prediction of infiltration,

runoff, and the potential volume of effective precipitation.

### Results and Benefits

This study will contribute to better scientific understanding of moisture flux in surface soil horizons in arid basins. The research will provide insights on the effects of structural and microphytic crusts, textural change at the crust/horizon interface, and vesicular structure on hydraulic conductivity. Specifically, a new approach to estimating hydraulic conductivity and matric potential/water content relations of soils in situ will be tested on agronomic, shrub interspaces. Experiments will help to examine and quantify the reduction in cross-sectional area available for soil moisture storage due to non-interstitial vesicles.

Problems with low infiltration capacity of crust-stabilized vesicular horizons occur naturally in arid and semi-arid regions throughout the world. Under intensive agronomic systems, stabilized vesicular structures may form during repeated irrigation and significantly restrict soil water uptake. Low infiltration capacity, associated with crusting and vesicular structure, is frequently observed in greenhouse flats following repeated watering. This study will probe this process, qualitatively and quantitatively. Better quantitative estimation will improve simulation modeling and make irrigation effects and rehabilitation success more predictable.

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USGS

April 1986 - June 1987

Research in Progress

WATER TRANSFERS FROM AGRICULTURE TO INDUSTRY:  
TWO UTAH EXAMPLES

Abstract

Comparative studies of the social effects of the sale of agricultural water to industry showed sales through collective bargaining, when compared to sales through individual negotiations between buyers and sellers, to bring greater satisfaction with the sales process but more antagonism among members of the community.

Principal Investigator(s)

Ronald L. Little (PhD), Sociology  
Jay M. Bagley (PhD), Civil Engineering

Student Assistant(s)

Thomas R. Greider (MS), Sociology

Increased population, changing levels of demand for energy, economic and political activities by oil-producing nations, and America's finite petroleum reserves have all combined to provide a strong stimulus for the development of Western energy reserves. Electrical power generation as well as the production of synthetic petroleum products from tar sands, oil shale, uranium, and coal, all abundant in the Intermountain West, require water and cause mounting political and economic pressure for the reallocation of water from traditional agricultural uses to the production of energy.

Water transfers from agriculture to industrial uses have implications beyond the economic and legal actions necessary for consummation of the transfers. The consequences extend far beyond the economic gains enjoyed by the nation, the companies involved, and the individual sellers or lessors of water. Water reallocations also change social structures and ultimately alter the lives of individuals and their communities.

While the consequences of resource reallocations are dimly perceived by rural residents most likely to be affected by water transfers and by social scientists alike, one outcome is clear. Changes at the individual level are quickly translated to the community and societal levels. Changes in lifestyles, occupations, and income for individuals alter existing social relationships among individuals and cause new patterns of social interaction to emerge as older patterns recede. These changes can be observed in both formal and informal structures. Former friendship and interaction patterns among individuals change. New political forces develop and the extent and diversity of economic activities may shift, expanding in some areas while contracting in others. All of these processes need to be probed so that they can be better understood by water project planners and the public alike.

Research Project Accomplishments

Data were collected on the social effects of transferring water from agricultural use to energy production in Millard County near Delta and Emery County near Castle Dale. Questionnaires were mailed to samples of water sellers and non-sellers in the two areas. Additionally, in-depth interviews were conducted with leaders in both communities.

The results indicate considerable difference between the two areas. These differences grew out of the varying methods used by the energy companies in obtaining water from previous owners. Purchases at one site were made through collective bargaining with the water sellers, while purchases at the other site were made through bargaining between buyer and seller at the individual level. Where selling was a unified effort,

there was much greater satisfaction with the process, and little desire for alterations in the process should future transfers be needed. Where the power company negotiated confidential sales with individual water owners, there was greater dissatisfaction and a perceived need for greater controls on future negotiations.

Both communities experienced dissension as a result of the water transfers. However, they differed in the focus of their hostilities. Where satisfaction with the sales process was reported, the antagonisms were among individuals. The hostilities were personalized as values and expectations about appropriate behavior were perceived to be violated. Where there was dissatisfaction with the sales process, antagonisms were directed toward the power company instead of other residents. While overt hostilities declined considerably between 1980 and 1982, covert hostilities remained evident. Changes in the community social structure appear to have occurred in both areas, but follow-up data are necessary to determine the nature and extent of the changes.

#### Publications

Little, R. L. and T. R. Greider. 1983. Water transfers from agriculture to industry: Two Utah examples. Research Monograph No. 10, Department of Sociology, Utah State University, Logan, Utah.

(Material presented to two professional meetings; two articles are in preparation for professional journals.)

#### Application of Research Results

The results of this research are in the process of being distributed to interested individuals in the two areas of Utah analyzed. Additionally, the report is being distributed to the two power companies, and to local and state level water resource and community development planners. The results of this research should be helpful in minimizing and mitigating the levels of conflict and hostilities produced by future resource reallocation and water transfers.

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Office of Water Research and Technology  
10/01/79-03/31/83, Agreement No. A-050,  
14-34-0001-0147, Research Completed, FCCSET  
Category III-B.

## HYDROLOGIC TIME SERIES GENERATION FROM THE SPECTRUM

Abstract

Exploration of the use of spectral characteristics to generate hydrologic sequences for water supply design and system operation showed the method deserving of refinement and application.

Principal Investigator(s)

Ronald V. Canfield (PhD), Applied Statistics

The design and operation of reservoir systems require reliable information on stochastic variation of the flow sequences, patterns over time of the flows at a given location and relationships among flows at various locations. These relationships are often sufficiently complex that classical synthetic flow generation methods cannot adequately preserve their stochastic properties. This study sought a realistic and computationally efficient model for generating hydrologic event sequences for water supply design.

Research Project Accomplishments

Present methods of generating hydrologic sequences are limited in their ability to preserve an observed autocorrelations structure. The use of spectral characteristics provides the alternative explored in this study. Because of the correspondence between the spectral density function and the autocorrelation function of a time series, the spectrum can be used to fit any correlation structure observed in hydrologic sequences. The problem of maintaining an observed correlation structure in a generated sequence is reduced to the much easier problem of maintaining the observed spectral characteristics.

A Monte Carlo model is usually designed to retain the observed autocorrelation of a natural sequence. Bias in the standard estimate of autocorrelation can be a particular problem in the generation of sequences. If the observed autocorrelation has been estimated with considerable bias, the asso-

ciated Monte Carlo model can lead to erroneous conclusions. A method for unbiased estimation of the autocorrelation function was developed and tested.

Application of Research Results

The generation of hydrologic sequences for water supply design and related water resources management applications may be substantially improved as this technique is perfected.

Publications

Canfield, R. V. 1982. Hydrologic series generation from the spectral density function with a Fourier transform. UWRL/H-82/04, Logan, Utah.

Office of Water Research and Technology, Agreement No. A-054, 14-34-0001-2147, 10/01/81 - 03/31/83, Research Completed, FCCSET Category: III-A

# PREDICTING CROP PRODUCTION AS RELATED TO DROUGHT STRESS UNDER IRRIGATION

## Abstract

Data obtained by growing several crops under carefully controlled experimental conditions in Utah, Arizona, Colorado, and California showed a strong linear correlation of production to evapotranspiration and were used to develop a model for estimating crop yield from information on local soil and climatic conditions and the pattern of irrigation over the growing season.

### Principal Investigator(s)

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J. Paul Riley (PhD), Civil Engineering  
Robert M. Hagan (PhD), Agronomy - California  
Ernest B. Jackson (PhD), Plant Science - Arizona  
William O. Pruitt (PhD), Irrigation Engineering - California  
Robert E. Danielson (PhD), Soils - Colorado

### Support Personnel

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### Student Assistant(s)

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The efficient use of land and water resources in food production requires a thorough understanding of the relationship for each agricultural crop between crop production and water supply in the root zone. Past work by the research team showed a direct relationship between corn yields and the volume of water used. The research has also shown that the relationship varies with soil, plant, and climatic conditions; but that for a particular set of these conditions, there exists a potential soil moisture extraction pattern. Thus, by defining the soil, plant, and climatic conditions at a particular site, one might predict the potential root moisture extraction pattern and thus the relationship between soil moisture and crop yield. The primary purpose of this project, then, was to develop and test a technique for predicting crop yields as a function of soil moisture available to the plants for known soil, plant, and climatic conditions. Data obtained by field measurements for several different crops were used to develop a mathematical model for application throughout the world.

In past studies to develop an understanding of crop production as a function of water supply, the research team developed an extensive data base on how corn yields respond to moisture deficiency and salinity stress within the root zone. Crop yields were found to vary directly with plant evapotranspiration (ET). The relationship between plant yield and root zone depends on the combination of soil, plant, and climatic conditions existing at the site under consideration. Thus once these relationships are established, one can by defining the soil, plant, and climatic conditions existing at a particular site, predict the soil moisture extraction pattern and, from information on the availability of soil moisture to meet this need, crop yield. The primary objective of the project was to generate data for defining the production function for different crops as influenced by moisture availability under different soil and climatic conditions. These data were used to develop and test models generally applicable for predicting crop production as a function of available water supplies within the root zone.

### Research Project Accomplishments

Field data were collected for sugar beets at Yuma, Arizona; Davis, California; Fort Collins, Colorado; and Logan, Utah.

The researchers at all four locations followed a single research plan to collect data that were used in models to evaluate

the influence of water deficits on crop production. Data were also collected to evaluate the influence of climatic and site factors.

The research on sugar beets presents data at all four locations on sucrose, fresh root and dry matter yield for five or

six replicated levels of water application. In addition, a comparison was made between total mid-season cut-off of irrigation and normal full season irrigation. Further comparisons are made of the influence on yield of four dates of harvest under both irrigation regimes. The experiment was further designed to have two different initial soil water regimes. In one, the soil was filled to maximum water holding capacity at planting time, and it was about half full for the other. For all treatments, measurements were made of irrigation applied (amount and time), soil water depletion, estimated drainage, and evapotranspiration and were supplied by stages during the growing season.

In addition, data for spring wheat, winter wheat, and barley are listed for Logan, Utah. Data were collected for pink beans and pinto beans at Davis, California, and for cotton at Five Points, California (40 km southwest of Fresno). Soybean data are reported at Fort Collins.

The field data show a generally strong linear relation between sugar beet production and ET for all four locations. The results can be characterized by the equation:

$$(Y/Y_m) = 1 - 1.3 (1 - ET/ET_m)$$

where  $Y/Y_m$  is relative yield of sugar beets and  $ET/ET_m$  is relative evapotranspiration. The relationship of this form shows a better correlation if each location is analyzed separately or if the full season irrigation is analyzed separately from the irrigation with mid-season cutoff. Even better correlation is found if each harvest date is analyzed separately.

With full season irrigation, yield and ET increased as the harvest date was delayed. However, a higher water use efficiency (yield/ET) was found at some intermediate harvest date. This was especially true at Yuma where beets were planted in the fall, grown through the winter months and harvested in the spring. The highest water use efficiency was found for the earliest harvest. At the three other locations, where planting occurred in the spring and harvest in the fall, the next to last harvest date (mid-October) generally gave the highest water use efficiency.

Models to predict the effect of water deficit on yield were found to give generally

good to excellent predictions. The models found useful for corn yield prediction in the earlier study were also found to give good predictions for sugar beets and for the other crops tested. The Stewart model, relating relative yield to measured relative ET, gave similar equations for all locations. Its simplicity promises to make it useful for predictive purposes in a wide variety of conditions. It was found that it is not necessary to account for growth stage effects to get good seasonal predictions of yield and yield components. This condition permits the model to be simplified and the data requirements reduced.

Overall, it was firmly established that there is a very strong linear relationship between yield and ET for a wide variety of crops. Thus, the most efficient water use is accomplished by supplying water to match crop needs in a manner that minimizes drainage below the root zone and takes full advantage of stored soil water during the season. If the soil water profile is full at planting time, a smaller portion of the crop needs are left to be supplied as irrigation water during the growing season, especially if the soil is deep with a high water holding capacity as that at Davis. In contrast, if the soil has a low water holding capacity, like that at Yuma, 80-90 percent of the ET needs must be met by irrigation during the season. The soil properties and the depth of rooting were found to be extremely important in determining the water requirements for the crop. Climatic factors were demonstrated to be important because of their relation to rooting depth. For example, the cool soils in Logan and Fort Collins had shallow root zones compared to Davis.

#### Application of Research Results

The research collected a broad data base on how water factors influence the production of several crops and used them to develop crop production models useful to economists, water resource planners, and agriculturalists. The models, developed to estimate crop yield from information on soil and climatic conditions and the pattern over the growing season of soil water availability, have broad geographic application.

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Office of Water Research and Technology,  
Agreement No. B-176, 14-34-0001-9139,  
07/01/79 - 06/30/82, Research Completed,  
FCCSET Category: III

#### Publications

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# EFFICIENT ALLOCATION OF WATER BETWEEN AGRICULTURE AND ENERGY THROUGH OPTIMUM TECHNIQUES OF WATER USE AND CONSERVATION

## Abstract

A model structured to determine the optimal capital investment in water conservation technology in agriculture (e.g., sprinkler irrigation systems), and in the public sector (e.g., canal lining and phreatophyte control) showed that public investment can only be justified by salinity control benefits.

### Principal Investigator(s)

Rangesan Narayanan (PhD), Economics  
Basudeb Biswas (PhD), Economics  
Jay C. Andersen (PhD), Economics

### Student Assistant(s)

Douglas Franklin (MS), Economics

In many areas of the West on the verge of extensive energy resource development, water is scarce. As the demand for water is increased by needs for energy production and associated economic growth, the competition will cause some water reallocation from agriculture to energy. The greater value of water in this competitive situation will be an incentive for greater water conservation in all uses. Furthermore, whether it is on the farm, in the home, or in the energy industry, water conservation requires investment in more capital-intensive water use methods. Many of these investments will be undertaken in the private sector (irrigation equipment for example), but a host of public investment alternatives for water conservation also need to be recognized. This study sets a framework for evaluation of the need for public investment in water conservation measures.

### Research Project Accomplishments

The available water conservation techniques, their capital costs, and the amount by which they reduce the consumptive use of water have been compiled for alternative agricultural and energy production uses in the Upper Colorado River Basin. The basic structure of the linear programming model has been developed to estimate the minimum total cost water conservation technology and its effects on salinity in the Colorado River.

The model optimally allocates, given a water conservation technology, water between agricultural and energy sectors in each of eight subregions in the Upper Colorado River Basin.

The linear program optimizations based on average annual flows indicate that public investment in water conservation schemes is not economically justified to supply water needs projected through the year 2000. However, public investment in water conservation is part of the least cost approach for meeting EPA standards for salinity in

the Colorado River. The specific figures recommended by the model to meet 1985 needs were an annual expenditure of \$9 million to salvage 284,000 acre-feet on measures to suppress reservoir evaporation, reduce transpiration losses from phreatophytes, and canal lining. If these public investments are not made and the Colorado River salinity standards are to be achieved, average annual private expenditures of \$12 million will be required.

### Application of Research Results

The model is designed to estimate for the Upper Colorado River Basin the optimal public investment in water conservation technology. The same technique is applicable on a larger scale in formulating a national policy with respect to water conservation.

Office of Water Research and Technology,  
Agreement No. B-185, 14-34-0001-9142, 01/01/  
79 - 03/31/82, Research Completed, FCCSET  
Category: III-E,F.

Publications

Narayanan, R., and D. R. Franklin. 1982. Efficient allocation of water between agriculture and energy through optimum techniques of water use and conservation. UWRL/P-82/07, Utah State University, Logan, Utah.

Narayanan, R., T. C. Hughes, and S. Orlovsky. 1983. Salinity management by use of low quality water. Working paper WP-83-18, International Institute for Applied Systems Analysis A-2361 Laxenburg, Austria.

DROUGHT MANAGEMENT CONCEPTS: LESSONS OF THE  
1976-1977 DROUGHT

Abstract

A multiple regression model of water use changes with price, a model for rationing a stochastically variable water supply, and an analysis of the economic impact of water management policies during drought showed regulation to be more effective than marginal price changes in reducing water use during drought, and the management policies followed in Salt Lake County during the 1977 drought to have caused substantial economic losses.

Principal Investigator(s)

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Herbert H. Fullerton (PhD), Economics  
Rangesan Narayanan (PhD), Economics

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Student Assistant(s)

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Hamid Fakhraei (MS), Economics

From the economic point of view, a drought may be defined as a water shortage resulting from a reduction in supply due to natural causes under conditions of fixed or lagging prices. A drought, depending on the degree of shortage, can result in effects ranging from small inconveniences to serious economic losses. Measuring the extent and severity of the consequent economic impacts to various users is an important step in examining drought management concepts. For industrial or agricultural sectors, drought losses can be measured in terms of foregone value of output. For the municipal sector, the concept of consumer surplus may be more appropriate. Under constant cost conditions, the more inelastic the demand for water, the greater will be the economic losses for a given reduction in the water availability.

Drought mitigation measures may consist either of ad hoc policies adopted after a drought has begun (such as rationing of water and damage relief programs) or long term policies such as pricing schedules which function through both average and drought periods. Both types of measures were analyzed in this study.

Research Project Accomplishments

Three mathematical models of drought management were developed. Each model was applied to particular locations in Utah using the hydrologic/economic data from the 1976-77 drought. The modeling approaches were:

1) A multiple regression approach to quantify the changes in water use achieved by three common municipal sector rationing policies: a) restrictions on time of outdoor

use, b) price increases, and c) mandatory quantity restrictions.

2) Determination of the optimal long term price schedule for rationing a stochastically variable water supply during summer peak demand seasons among groups of municipal water users which have different demands.

3) Analysis of management policies in terms of their impact on net benefits to the agricultural and municipal sectors. The model

is capable of modifying policies monthly, based upon the changing hydrologic situation. It can vary constraints in a manner that simulates an institutional environment ranging from total freedom of price changes and water exchanges between sectors to those constraints existing during the 76-77 drought.

Conclusions include: 1) Mandatory water use regulations are much more effective than price increases in reducing water use (at least for the short term during drought). 2) A theoretical analysis of demand and supply functions showed that Salt Lake City's pricing policy (about \$0.25/1000 gallons) is very close to optimal. 3) Substantial losses in consumer surplus in Salt Lake County during the drought were caused by various institutional restrictions.

#### Application of Research Results

The methodology developed in this report is available to any water utility for use in setting pricing policies. Since the pricing

models are presented in generalized form, no site specific limitations exist. The policy effectiveness regression model is based upon Utah municipality data only. However, the results should apply with reasonable accuracy over most regions with a similar semiarid climate.

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Office of Water<sup>04</sup> Research and Technology,  
Agreement No. B-214, 14-34-0001-1271, 10/01/80  
- 03/31/83, Research Completed, FCCSET  
Category: III.

#### Publications

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DEVELOPMENT OF A COMPREHENSIVE UPPER COLORADO RIVER BASIN  
MODEL FOR ANALYZING ENERGY DEVELOPMENT IMPACTS

Abstract

Eight past modeling directions are examined in terms of their technical capabilities, data limitations, and institutional acceptability to start formulating a framework for systems operation and water resources management in the Colorado River Basin.

Principal Investigators

A. Bruce Bishop (PhD), Civil Engineering  
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Support Personnel

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Student Assistants

Matthew T. Nussbaum (BS), Economics  
Scott Stoddard (MS), Civil and Environmental Engineering

Over recent years, a number of water quantity and quality models applicable to the Upper Colorado River Basin have been constructed. The models utilize a broad range of physical, simulation, and optimization approaches and have varying degrees of spatial, temporal, and parametric resolution. They have been used by various public (government agencies and universities) and private organizations; and, consequently, they have widely differing analytical and evaluative purposes and objectives. Since economic development has basin-wide effects on water resources, it is important to have a common set of quantitative management tools that can be used in all parts of the basin for water supply, water quality/salinity control, and environmental management by all parties concerned with policy analysis and planning. The ultimate need is for a common comprehensive model that provides an organizing focus for identification and guidance of systematic research on critical water-energy issues.

Efforts to model the Colorado River system mathematically have been relatively recent. Previous studies established baseline historical data on flows, water quality, land classes, and environmental conditions. It is interesting in this regard to trace basin development and related social concerns by historical period. In the 1800s, irrigation was begun by individual farmers and expanded when farmers joined to construct common facilities to water their lands. The settlement and development of the West became a national policy when Congress passed the Reclamation Act of 1902.

Over time, the need for a more dependable supply pointed to larger water storage reservoirs. Proposals for storage in the lower basin without protective guarantees were regarded by the upper basin states as threats to established priorities. The Colorado River Compact, approved by the basin states and Congress in 1922, was supposed to remove the rivalry between the two basins. The Boulder Canyon Project Act was passed in 1928 and the first water was stored behind the dam in 1935, harnessing the lower reaches of the river and achieving a major reclamation milestone.

Because of the degree of control that man can now exercise over the Colorado River flows, management in the 1990s is expected to emphasize operation of the system. Some of the key factors likely to impact on system operating and management decisions are completion of basin development projects, transmountain diversions to serve larger urban areas, development pressures within the basin, and flood control. This growing need has been accompanied by a research interest in developing basinwide computerized water resources models to analyze various development alternatives. The literature on research and engineering studies and on modeling development shows parallels between values and development policy and the types of models being produced. From these comparisons and contrasts, an integrated modeling approach for the Colorado River Basin can be conceptualized. This study provides a first step.

#### Research Project Accomplishments

In the past two decades, scores of modeling studies have addressed one or more water resources issues in the Colorado River Basin. The models come in a variety of types (simulation, optimization, input/output, etc.) and vary in their geographical resolution, their extent of coverage of the Basin, the water uses they incorporate, and potential management applications. Many modeling studies were reviewed in terms of the water resource issues they address, their relevant management applications, and the types of modeling approaches they represent. This was followed by a more detailed review of the modeling studies that were judged to be most useful for application in the Colorado River Basin.

Eight models (or sets of models) were judged to be the most useful in examining present and future Colorado River Basin water resources problems. "Usefulness" was assessed on the basis of geographical coverage, the number of water issues addressed, and the quality of the approach. The models given detailed review were:

1. A steady-state mass balance simulation of water and salt flows representing 16 subbasins from the headwaters of the Green River to Imperial Dam as done for the National Commission on Water Quality (Bishop 1977).

2. A non-linear programming model done at Colorado State University of the entire Upper Basin to determine the least-cost salinity-control strategies (Walker et al. 1979a and 1979b, Skogerboe et al. 1979, and Evans et al. 1983).

3. A mixed integer linear programming model examining the effects of energy and irrigation development on surface water availability and salinity programmed at Utah State University by Narayanan and others (Narayanan et al. 1979, Narayanan and Franklin 1982).

4. A linear programming model done at Utah State University by Snyder et al. (1981) to examine the impacts of energy development on the availabilities of water to agriculture.

5. A 31-sector regional input-output model applied at the University of Colorado to analyze the impact of salinity in the water on economic activity in the Upper Basin (Howe and Orr 1974 and Udis et al. 1976).

6. A chance-constrained dynamic programming model in which Cummings and McFarland (1977) optimized water allocation in the Upper Basin given that the flows are stochastic and that Upper Basin storage is limited.

7. A set of mixed integer and dynamic programming models applied by Erlenkotter and Scherer (1976) to the investment planning of salinity control projects.

8. A series of models constructed by the U.S. Bureau of Reclamation, including:

- a) an analysis of salinity damages by Kleinman (1976);
- b) the streamflow simulation model reported by Huntley et al. (1976); and
- c) the River Network Program developed by Ribbens (1976) and used by Weber et al. (1976).

These eight efforts provide a sound starting point for modeling for water resources systems operation and water use management in the Colorado River Basin. They address diverse aspects of the system and can be brought together in a general framework for planning and for providing policy makers reliable information on the implications of decision alternatives. The project report presents guidelines for their integration to achieve their technical capabilities in the contexts of data limitations and constraints on institutional acceptability.

### Application of Research Results

Much more work will be required to build from this appraisal to a comprehensive modeling framework for river basin planning. Hopefully, this pause to reflect on the present situation and the principles that should govern future modeling directions will ease the way toward an effort that can greatly increase the benefits achieved by water management in the Colorado River Basin.

### Publications

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(Final report being revised for UWRL publications.)

Bishop, A. B., R. Narayanan, M. McKee, and M. T. Nussbaum. 1984. Development of a comprehensive Upper Colorado River Basin model for analyzing energy development impacts. Final Report, Utah State University, Logan, Utah. (in rewrite)

OVERCOMING PROBLEMS OF SMALL PRIVATE WATER COMPANIES IN  
MAINTAINING SAFE, DEPENDABLE, AND COST EFFECTIVE  
DRINKING WATER SERVICE

Abstract

The regulatory structure dealing with characteristically small private water companies in Utah has not been effective in providing a safe, dependable, low cost water service; and administrative revisions are recommended.

Principal Investigators

Jay M. Bagley (PhD), Civil Engineering  
Frank W. Haws (MS), Civil Engineering

Small privately-owned water distribution companies experience a disproportionate number of problems in providing dependable service that consistently meets safe drinking water standards. Not only do these companies have a higher incidence of violations of water quality standards, but they often experience problems with financing and with system operation and management.

The reasons that these systems experience an abnormal incidence of problems need to be determined so that water purveyors, community planners, land developers, lending institutions, public utility commissions, regulatory agencies, and home buyers and owners can take appropriate measures for ensuring dependable, safe, and cost-effective service.

Research Project Accomplishments

Private domestic water purveyors in Utah operate as 1) customer owned (mutual) non-profit systems and 2) investor owned companies selling domestic water for profit. There are 142 privately owned water systems of which 18 (13 percent) are regulated by the Public Service Commission (PSC) as private water utilities. The most salient generalization about private water systems in Utah is that they are small. Only two serve populations greater than 10,000. All but one of the investor owned companies serve populations less than 650. Altogether, private companies serve only about 4 percent of Utah's total population even though private systems represent 15 percent of the total number of community systems. Regulated companies serve less than 1 percent of Utah's population with the largest company (White City) accounting for two-thirds of that total.

The incidence of violations of the Safe Drinking Water Standards and Procedures relates strongly to system size. Per capita costs of service is generally higher for small systems and cost differentials are even more exaggerated for the many small systems that are located in remote locations, and where

terrain and climate are more severe. Full-time and well-trained operators cannot be justified. On a per capita basis, costs for standby equipment, system repairs, and replacement are very high. For the regulated companies, costs relevant to the rate determination process add significantly to the overall costs.

Private water companies in Utah, both mutually owned and investor owned, are ineligible for the subsidized lending and granting programs of state agencies. If the objective of these programs is to obtain greatest health benefits and/or greatest reduction in compliance problems generally, then eligibilities based on organizational type might need reexamination. Private water companies also allege that they are subjected to different standards of proving and quantifying beneficial needs and uses by the State Engineer as contrasted to their public counterparts.

A common source of contention between customers and owners of private utilities is that the strategy or ultimate plan for perpetual water service is not made clear early on. Developers absorb much of the system operating cost pending sale of lots and



establish unrealistically low budgets for providing the water service. If lot sales are slower than expected and cash flow problems materialize, it becomes necessary to increase water rates so as to place the operation on a self-sustaining basis. Characteristically, the gap to be made up is large and provokes strong feelings among residents who see this as monopolistic abuse.

It is very burdensome and costly for small water companies to pass through the rate determination process of the PSC. In view of the fact that regulated companies are so small and currently operating with much lower rates of return than is characteristic of the major utilities; cannot provide scale economies to customers as large utilities can; are kept in line by customer potential to turn to individual wells or annex to a special service district; are regulated as to quantity and quality by the State Engineer and the Bureau of Public Water Supplies; serve such a small population of the state's population; experience high unit costs pertaining to regulation; and thus cannot actually take advantage of their monopoly status, it is indeed appropriate to consider changes that will improve the social profitability of such companies.

One possible change would be to establish threshold populations below which systems would be subject to a much simpler set of regulatory policies commensurate with their size. Another minor modification in the realty disclosure statutes making it mandatory for developers to declare and put into effect their strategy for perpetual water service would remove the kind of uncertainties and delays which are presently responsible for owner-customer conflict.

Simply taking the PSC out of the business of regulating small water utilities may be

another solution that deserves consideration. There seems to be more justification for reducing PSC involvement than for increasing it.

#### Application of Research Results

The findings of this study provide a much better perspective of the nature and magnitude of problems experienced by both purveyors and regulators with respect to private water service. Results should prompt some reevaluation of operating policies and procedures currently followed in the regulation of small water utilities. The small number and small size configuration of private water utilities in Utah make it impractical to subject such companies to the formal processes that are adapted to major utilities affecting large populations. Results suggest that a minor revision in the Utah Land Sales Practices Act requiring a declaration of the organizational framework to be used and similar modifications in county ordinances and the State Health Code would eliminate potential problems of customer haziness about intentions and the developer tendency to underbudget for system operation.

Study findings will be of value to land developers contemplating the most appropriate means of providing the necessary water service for their subdivisions.

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U.S. Geological Survey Cooperative Program,  
Utah Water Research Laboratory  
07/01/84 - 07/01/85  
Research Completed

#### Publication

Bagley, J. M., and F. W. Haws. Problems of small privately operated water companies in Utah. UWRL/P-85/01, Utah State University, Logan, Utah.

NONPOINT TRANSPORT MODEL FOR INDICATOR BACTERIA  
FROM WESTERN RANGELAND WATERSHEDS

Abstract

Bacteria movement from cow manure during rainstorms and thence downslope toward a channel were measured and used to calibrate a model for quantifying bacterial movement from wild or rangeland watersheds and how that movement varies with grazing intensity.

Principal Investigator(s)

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Student Assistant(s)

Everett Springer (PhD), Watershed Science  
Richard Thelin (BS), Watershed Science  
Mike Kress (MS), Watershed Science  
Kevin Conner  
Rex Hamner

National concerns for environmental protection and safe drinking water for small communities are focusing attention on bacterial pollution originating from rangeland watersheds. The magnitude of this problem needs to be estimated. Should current uses of range watersheds be causing a problem, land management concepts need to be examined to determine what they can do to improve the situation. If the problem is important and land management practice changes can help solve it, the practices on public lands need to be revised in the interest of water quality management.

Research Project Accomplishments

Grazing is a primary land use in much of the western United States, but little is known about grazing impacts on water quality. The most sensitive water quality indicators of grazing are the fecal indicator bacteria. The objective of this study was to develop a general transport model describing the movement of fecal indicator bacteria from upland sources to channel systems.

Model development was done using simulated rainfall and a runoff surface 30.48 m by 1.83 m. Initially, a runoff surface of smooth concrete was used to examine the effects of distance from the outlet on coliform counts by locating fecal material at various distances for five replications. Afterwards, the concrete was covered by clay soil and the experiment was repeated on the soil surface. Total fecal coliforms were determined by the multiple-tube method.

Overland flow was described by the kinematic wave equations. Bacterial transport was modeled with a random ordinary differential equation. Initial conditions and assumptions allowed solution for the probability density function (pdf), means, and variances. For the concrete surface, comparison of predicted and observed means

and variances indicated poor fits during initial stages of simulation. Observed values attained steady state rapidly. There was no replication on the soil surface, and an initial run found high background counts. Background counts were considered to be constant and incorporated into the mean equation. A numerical solution to the mean equation was required because of the unsteady rainfall excess. The background counts and clay content of the soil prevented detection of impacts from a single source.

Studies on point loading characteristics were continued. Emphasis concentrated on the impact of recurrent rainfall events on coliform release patterns, the impact of age of the fecal deposit on coliform release patterns, the impact of rainfall intensity on release patterns, and the differential response (if any) between our "standard" fecal deposits and undisturbed fecal deposits. Results indicate that a log-log regression describes the decline in peak fecal coliform counts with fecal deposit age; that rainfall intensity has little impact on fecal coliform release; that peak fecal coliform counts were significantly lowered by raining on the fecal deposits more than once; and that our "standard" cowpies did not behave differently from natural fecal deposits.

#### Application of Research Results

This project will provide baseline work for development of a preliminary model describing bacterial movement in wildland watersheds. The model will be useful in predicting water quality with various land management practices and in designating quantitative design criteria for riparian zone management.

Office of Water Research and Technology and Utah Agricultural Experiment Station, Agreement No. A-048, 14-34-0001-1046, 10/01/79-03/31/82, Research in Progress, FCCSET Category: V-A,B

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Springer, E. P. 1982. Nonpoint source transport model for indicator bacteria from western rangeland watersheds. PhD dissertation, Utah State University, Logan, Utah.

Thelin, R., and G. F. Gifford. Fecal coliform release patterns from fecal material of cattle. Journal Environmental Quality.

(Manuscript in preparation for Water Resources Research.)

# ENHANCEMENT OF TRANSPORT AND AVAILABILITY OF HEAVY METALS TO AQUATIC MICROFLORA BY COMPLEX ORGANICS ASSOCIATED WITH OIL SHALE DEVELOPMENT

## Abstract

Leachate from spent oil shales were examined to determine their propensity to complex with several heavy metals and create soluble toxic substances that are environmentally harmful.

### Principal Investigator(s)

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Frederick J. Post (PhD) (Microbiology)

### Student Assistant(s)

Bruce Mok (MS), Environmental Engineering

Leachates from spent oil shale and oil shale process waters contain organic molecules that form complex associations with toxic heavy metals and thus increase their solubility. Although it has been known for some time that natural organics, such as those produced by the decay of leaf litter, can affect the mobility and toxicity of heavy metals, little is known about any similar reactions associated with these new man-made organics. Potential short-order ecologic effects of toxic metal-organic complexes include enhanced toxicity to aquatic organisms or, conversely, detoxification of ambient metal concentrations. The purposes of this research are to look for complexing organic compounds (or ligands) in various molecular size fractions of oil shale leachates in order to determine the toxicity of metals complexed by such organics to algae, and to develop mathematical formulae that describe the degree and strength of metal/organic interactions.

### Research Project Accomplishments

Unretorted oil shale leachate, in the absence of added heavy metals increased algal growth in bioassay tests, and the growth stimulant was found to be in the high molecular weight fraction. In fact, both dissolved salts and low molecular weight organics (<500 amu) in the leachate were inhibitory when tested alone. All size fractions of Paraho retorted shale leachate stimulated growth.

When heavy metals were added, unretorted shale leachate at a concentration of 5 mg/l TOC was found to reduce the toxicity of copper by a factor of 16. This leachate detoxified cadmium by a factor of 8 at low (1 mg/l TOC) concentrations, but it was inhibitory at higher TOC concentrations and at all concentrations in the presence of nickel. Retorted shale leachate also detoxified copper.

Chemical analyses of thermodynamic binding constants and complexation capacities were carried out using anodic stripping voltammetry, ion-selective electrode titrations, and continuous ultrafiltration. The complex nature of the matrix caused problems

with all of the techniques, but the resulting data showed good agreement when the corresponding mathematical models were compared with bioassay results.

The studies revealed that the active ligand in oil shale leachate is not a nitrogen heterocycle, as has been suggested for retort water, but a humic acid-like organic of high (>500 amu) molecular weight and exhibiting approximately half the affinity for copper found in humic acid from organic soils. Consequently, unless organic carbon concentrations from oil shale leachate exceed those from native humic and fulvic acid inputs to receiving streams, it is unlikely that this factor will significantly affect the toxicity or transport of heavy metals in areas where shale piles are stored. However, dissolved salts or low molecular weight organics from oil shale leachates may affect algal growth in receiving streams or reservoirs.

### Application of Research Results

Knowledge of metal binding capacity of spent oil shale leachate and leachate/surface

water mixtures helps water quality experts predict the effects of accidental catastrophic or low level chronic contamination of surface streams from spoil piles. The mathematical formulations will be useful in environmental water quality modeling and for model stream and soil microcosm experiments.

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Office of Water Research and Technology,  
Agreement No. A-051, 14-34-0001-1147, 10/01/80  
- 03/31/83 Research Completed, FCCSET Category: V-B,C.

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## IN-CHANNEL SALT-SEDIMENT RELATIONSHIPS IN THE COLORADO RIVER BASIN

### Abstract

Field observations, laboratory experiments, and mathematical modeling were used to estimate salt loading by salt efflorescence carried away by streamflow and from salts released by sediments washed or sloughed into channels to be a relatively small portion of the total in the Upper Colorado River Basin.

#### Principal Investigator(s)

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#### Support Personnel

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#### Student Assistant(s)

Hooshang Nezafati (PhD), Civil Engineering  
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Rising salinity levels in the Colorado River are causing increasing losses where river water is used for agricultural, municipal, and industrial purposes in the United States and Mexico. One way to curb this trend is by developing a better understanding of the physical processes by which salinity enters the rivers and is transported downstream. Many other loading processes have been examined, and now specific attention needs to be given to salinity loading from suspended sediments and from efflorescence or salt crusts on the streambeds.

Field data indicate that salt carried by fluvial sediments is an important source of salinity in the Price River. Little is understood about the chemistry of salt release by sediment transported in a stream. Methods are needed for estimating the amounts of salt released into the water from suspended sediments and how the release rate varies with sundry controlling factors. In addition, the processes of formation and dissolution of salt crusts, called efflorescence, in ephemeral channels need to be studied to determine 1) the salt sources, 2) the rate of crust formation, and 3) the contribution to overall salinity. By learning more about these physical-chemical processes, we will better understand 1) the sources of salinity in the Colorado River and its tributaries, 2) the effects on salinity of altering sediment transport characteristics by flow regulation, and 3) the impact on salinity of the increased sediment load caused by such activities as mining and agriculture.

#### Research Project Accomplishments

Salinity control is a major component of water management in arid climates and irrigated areas and one of particular concern in the Colorado River Basin. The salts enter the water as it flows over land or moves through the soil or geologic formations. The principal salt collection processes are 1) dissolution from the soil surface during runoff events, 2) transpiration of soil water leaving salt residuals, 3) efflorescence left by evaporating seepage and then dissolved by subsequent runoff, 4) dissolution with weathering of fixed bed channels, 5) salts released by sediments entering the channel from sheet, gully, and bank erosion, and 6) deep percolation through saline aquifers reaching the stream as base flow. This study examined processes 3 and 5.

Salt efflorescence was examined by field observation and instrumentation, laboratory

experiments, and mathematical modeling. The field data showed near saturation conditions of sodium sulfate waters below crusts of densities between 0.14 and 0.36 g/cm<sup>2</sup> and which formed over about a 10-day period following channel cleaning by storm runoff. Laboratory data on salt crusting in soil columns were also used in developing a model which when applied to the Price River Basin estimated that no more than 7.5 percent of the total salt loading comes from salt efflorescence being carried away in the stream flow. The conditions favorable to the accumulation of salt efflorescence are highly saline water just below the soil surface and a source of heat for vaporizing the water.

Salt release from suspended sediments was studied by laboratory experimentation with sediment material obtained from various locations in the Price River Basin. The Buckingham Pi Theorem was employed to derive

relationships expressing the EC of a sediment water system as a function of the controlling factors. The results were presented in two salt release equations, one excluding the effect of initial EC and the other providing for initially saline solutions. The salt release equations were incorporated into an adapted version of the Watershed Erosion and Sediment Transport (WEST) model and applied to a small tributary of Coal Creek. Extrapolation to the entire Price River Basin led to an estimate that about 0.50 percent of the total annual salt load is released from suspended sediments.

This study concluded that surface salt sources produce a relatively small fraction of the total loading. Future studies need to go underground. They need to quantify and examine the flow lines of water movement from mountain source and valley floor recharge areas to points of emergence as base flow in the larger stream channels. They need to investigate the aquifers and their soluble salt content.

#### Application of Research Results

The understanding obtained from the project is useful to agencies charged with preventing further increases in the salinity content of the Colorado River. Salt source modeling is essential to assessments of the effectiveness of upstream treatments on downstream reaches and of the effects of reallocating water from agricultural to energy uses on salinity levels in the Colorado River.

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12/31/81, Research Completed, FCCSET Category: V-B.

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B-172 (WG-242)

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THE EVALUATION OF HEAVY METALS AND POTENTIALLY CARCINOGENIC  
ORGANICS RELEASED INTO COAL MINE AND OIL SHALE ACCRUAL WATERS

Abstract

Metal and organic compounds leached during coal mine and oil shale accrual water formation and the factors which regulate that leaching process were examined with the finding of relatively minor adverse effects on the water quality standards needed for irrigation, aquatic environments or drinking water safety.

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Recent years have seen considerable effort being placed on locating and developing coal and oil shale reserves, especially in the intermountain west. This development needs to be carefully coordinated with water supply management and water quality control. Surface and groundwater enter mines or are used during mining operations and are then collected, treated and eventually discharged back into streams and often at least indirectly into irrigation canals. Water quality regulation requires information on the possible effects on the aquatic environment and agriculture of the water having been in contact with coal or oil shale or otherwise diverted through the mining operation (accrual water). Earlier research indicated that contact with coal or oil shale may increase a water's content of total dissolved solids, strontium, aluminum, manganese, boron, fluoride, sulfate, and carcinogenic organics. This study sought information on the magnitude of these increases under varying conditions and also attempted to evaluate each coal mine's accrual water treatment systems.

Research Project Accomplishments

This research resulted in two publications. The first, "Evaluation of the Potential for Groundwater Transport of Mutagenic Compounds Released by Spent Oil Shale" by Robert E. Hinchee, V. Dean Adams, Jeffery G. Curtis, and Alberta J. Seierstad, UWRL/Q-83/06, focused on the potential mutagenicity of aqueous leachates from spent oil shale. Additional mutagenicity testing was also done on raw shale and coal.

The Ames salmonella microsomal bioassay was used to test for chemical mutagenicity. Spent oil shales from the Paraho and TOSCO II processes, a raw shale from Anvil Points, and a composite coal sample from the Wasatch plateau were extracted with water and organic solvents. Only organic solvent extraction of

the TOSCO spent shale resulted in a mutagenic response. The lack of mutagenic response to organic extracts of Paraho spent shale was unexpected and was probably due to higher than typical temperatures at which it had been retorted.

Using TOSCO spent shale leachate and the organically extracted mutagen, a partition relationship between the spent shale and leachate water was developed. The mutagen was found to have a fairly high affinity for spent shale. Based on this it was estimated that mutagenicity of the TOSCO spent shale leachate will be low (in the range of chlorinated wastewater), however it will require many pore volumes to leach out of a pile potentially resulting in a chronic long-term problem.



The second publication, "The Evaluation of Metals and Other Substances Released into Coal Mine Accrual Waters on the Wasatch Plateau Coalfield, Utah" by Alberta J. Seierstad, V. Dean Adams, Vincent A. Lamarra, Nancy J. Hoefs and Robert E. Hinchee, UWRL/Q-83/09, summarized the study of six sites on the Wasatch Plateau representing subsurface coal mines which were discharging or collecting accrual water. Water samples were collected monthly at these sites for a period of 1 year (May 1981 to April 1982). Samples were taken before and after each mine's treatment system. Water samples were analyzed for major anions and cations, trace metals, physical properties, nutrients, total organic carbon, oil and grease, trihalomethanes, and algal assay. Predictions were made as to the possible effects these coal mine accrual waters would have when used for drinking water, irrigation water, stock and wildlife watering, and as discharges into freshwater aquatic ecosystems. Compliance of the mine water discharges with NPDES regulations was also noted.

Crushed coal samples were obtained from each of the six mine sites and evaluated with regard to their leaching characteristics in laboratory upflow leaching columns using an aqueous leaching medium characteristic of the area's water supplies. Leachate samples were analyzed for major anions and cations, trace metals, physical properties, and total organic carbon. Laboratory leaching characteristics were compared to the chemical nature of the actual mine water discharges. Mine water discharges were not found to be acidic in nature, the values for most parameters monitored during the field and laboratory portions of the study fell below the toxicity criteria for uses mentioned above, and were generally in compliance with NPDES regulations.

Boron was present in the mine waters, but at levels which would be predicted to cause only minor or no damage to the most sensitive crops. The drinking water limit and the freshwater aquatic life bioaccumulation criterion for mercury were exceeded on several

occasions in the coal mine accrual waters sampled. A comprehensive study of fish tissue samples and water samples taken from bodies of water near coal mines is recommended.

Total suspended solids (TSS) and oil and grease were among the most frequently violated parameters with regard to NPDES regulations. Further studies are recommended with regard to the effects of these substances on stream biota, their sources and their fate in aquatic ecosystems.

Coal leaching trends in the laboratory column experiments paralleled many of the trends observed in the field data collected. Trends for pH, aluminum, arsenic, beryllium, cadmium, chromium, cobalt, copper, iron, lead, molybdenum, nickel, silver, zinc, boron, lithium, strontium, alkalinity, chloride, fluoride, potassium, sodium, and silica were generally consistent when these comparisons were made. Values for water hardness parameters were observed to be specific to the mine site involved and not always comparable to laboratory leachate column data.

Generalizations with respect to leaching trends and origins of chemical substances in coal mine accrual waters must be made with caution due to the great potential variability in coal samples and the complexity of leaching phenomena.

#### Application of Research Results

The results provide a quantitative basis for estimating the environmental impacts of discharging coal mine accrual waters in Utah and for evaluating potential groundwater transport of mutagens from coal and raw and spent oil shale.

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and State of Utah Special Appropriation to  
University of Utah, Agreement No. B-210,  
14-34-0001-1273, 10/01/80 - 09/30/82, Research  
Completed, FCCSET Category: V-A,B.

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## EFFECTS OF COMPLEXATION WITH OIL SHALE LEACHATE ON HEAVY METAL BIOACCUMULATION

### Abstract

Stream microcosms, using Logan River water and natural substrates, perfusion columns, and crop studies were employed to examine cadmium complexing in the presence of raw oil shale leachate, transport through aquatic ecosystems, and the effects on ecosystem health and crop productivity.

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Organic compounds in the leachate from spent oil shale and in oil shale process waters form metal-organic complexes. If it were not for such organic compounds, most heavy metals in hardwater streams would be deposited in the sediments through adsorption and co-precipitation. By this means, metal organic complexes may mobilize harmful levels of such heavy metals as cadmium in aquatic and soil systems. The transport mechanisms of these metal-organic complexes in aquatic and soil environments are poorly understood, but potentially important processes related to transport include: 1) solubilization by organic ligands from insoluble minerals in stream or lake sediments or from soils, 2) sorption onto a clay or calcite mineral particle, where it may ultimately be released as the particle is deposited in downstream reservoir sediments, 3) transport downstream attached to suspended particles possibly through water treatment facilities or onto irrigated fields, and 4) photooxidation by sunlight or degradation by microbial activity, resulting in the release of free metal to the environment.

However these processes interact, heavy metals that enter the biotic community can significantly alter both the structure and function of an ecosystem. In aquatic systems, metals may alter the community composition so that economically important fish populations are reduced or lost. Alternatively, heavy metals may accumulate in fish species consumed by man. Heavy metals in irrigation water may alter the soil microflora community, reducing the productivity of agricultural lands, or bioaccumulate in crops to the point where the plants become useless as a food source. The purpose of this research is to elucidate the transport mechanisms and eventual fate of a metal complex in both an aquatic and a soil system and to produce a model to aid in the prediction of aquatic ecosystem responses to the addition of complex forming organic matter and metal ligands.

#### Research Project Accomplishments

The UWRL stream research facility houses 8 stream microcosms in a 20' x 60' greenhouse (Figure 1). Each stream consists of an upstream riffle, a pool, and a downstream riffle. The riffles were seeded with substrates from the Logan River and the pools

with sediments from the White River in Colorado. The streams operate on a flow-through basis with water taken directly from the Logan River. This mode of operation provides a continuous supply of fresh water and a constant source of colonizing organisms which enter as drift.

The streams were monitored to obtain baseline characteristics. Water quality parameters recorded included temperature, pH, dissolved oxygen, nitrogen and phosphorus species, and total organic carbon. Biotic monitoring included drift in and out of streams, quantitative benthic invertebrate samples, algal colonization rates, phytopigment ratios and qualitative observations. The streams developed rich communities of algae, macrophytes, and invertebrates typical of lotic habitats in the Intermountain West.

Low levels of cadmium (20 µg/l) were applied to four of the eight streams for a 3-week period. Two of the cadmium-treated streams and two streams not receiving cadmium were exposed to 27.2 kg of crushed unretorted oil shale. At the end of the treatment period, the stream communities were examined for effects on invertebrate density, diversity, and population dynamics or for altered photosynthetic pigment ratios and growth rates in the algal communities. These examinations found no significant differences between either the oil shale or cadmium treated streams and their respective controls.

To identify the fate of the metal introduced into the streams, the cadmium content of the algae, macrophytes, invertebrates, and pool sediments was measured. The algal films accumulated an average of 1000 µg Cd/g dry wt, the highest accumulation of any of the stream biota. Other cadmium concentrations in µg Cd/g dry wt were: 230 in macrophytes, 160 in invertebrate grazers, 90 in invertebrate particulate feeders, 8.0 in predatory stream invertebrates, and 0.35 in the pool sediments.

Laboratory studies of algal films and a benthic invertebrate grazer (the caddisfly *Brachycentrus*) indicated that much of the metal accumulation in hardwater stream communities ends up in cell and body surfaces, a fact which may help to explain the lack of observed effects in the cadmium-treated streams. High accumulations, like those observed in the algal films and grazers, from low level cadmium exposure for a short time period is cause for concern since these biota serve as food for sport fish. The potential for cadmium transfer to sport fish via contaminated food should be investigated.

To assess the potential agricultural impacts of pollution from cadmium and oil shale leachate, perfusion column and crop studies were conducted. In the perfusion column studies, using soils from the oil shale region, nitrification was unaffected by treatments of 20 µg Cd/l, but nitrification appeared to be enhanced by the organic frac-

tion from concentrated unretorted oil shale leachate. The conclusion was that neither cadmium nor oil shale leachate diluted by irrigation water is likely to adversely affect nitrification processes in agricultural soils. In crop studies, potted plants (alfalfa and radishes) were irrigated with oil shale leachate and 20 µg/l cadmium. Oil shale leachate appeared to enhance cadmium accumulation in alfalfa roots; however, the cadmium accumulations in the edible portions of these plants would not present a hazard to human or animal health.

#### Application of Research Results

The results of this research have broad applications in analyzing and mitigating the impacts of mining or industrial processes which produce cadmium wastes or organic matter capable of binding heavy metals. Regulatory agencies and private producers gain ability to predict the environmental consequences of disposal or accidental release of cadmium into a stream ecosystem or onto an agricultural soil. Reliable prediction can reduce the cost of waste disposal programs by preventing the overdesign of treatment facilities and shale leachate containment structures. Regulatory agencies can use the results in setting reasonable guidelines for industry in management of leachates and metal bearing waste streams.

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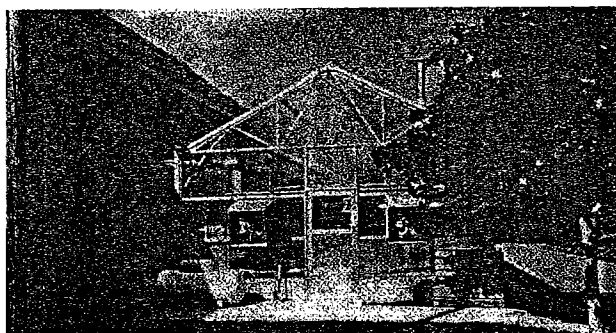


Figure 1. The RIFFLE facility.

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MODELING RELATIONSHIPS OF SALT TRANSPORT FROM IRRIGATION AND  
WEATHERING OF UNDERLYING SEDIMENTS: THE PRICE RIVER BASIN

Abstract

Quantification of groundwater flow, salt transport, and geochemical interactions, between the water and the soils and among the waters, is combined in a single model being applied to an irrigated area in the Price River Basin in order to determine how water may be better managed in irrigated areas to reduce salinity loading.

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Irrigated agriculture in the Upper Colorado River Basin has been associated with increasing salt loadings to the river and has been the target of a number of control measures to reduce the resulting downstream adverse effects. In order to protect the Lower Basin water users with minimal disruption of Upper Basin agriculture, quantitative information on the salt sources and the factors controlling the loading rates is essential. An effective salinity control program starts from quantitative relationships estimating salt loading rates and specifically including the controllable parameters.

Recent studies have shown that groundwater is a major contributor to stream salinity in the Upper Colorado Basin. The primary sources are the marine shales and shale residuum that underlie the soils of much of the basin. Water leaches the salts from these shales and carries them to the stream. The quantitative relationships needed for salinity control program formulation are those describing the movements and mixing of natural and irrigation waters through these formations and of the physical and chemical factors controlling the interactions between the waters and the shales.

This study is examining the salt loading processes at a field site in the Price River Basin by developing and calibrating a field-scale model to describe the geochemical interactions and mixing of subsurface flows on salinity transport. The calibrated model can then be used to build understanding of the processes active at a given location and to assess proposed salinity control measures. The conceptual model developed in this study indicates that diffusion of salts from low permeability strata plays an important role in the salinization of streams and rivers in the region.

Research Project Accomplishments

The study began by developing a conceptual model of the mixing and chemical interaction of natural groundwaters moving through underlying saline geologic strata with deep percolation from irrigated agriculture. The model was then applied to a field site in the Price River Basin to identify and estimate

the important parameters of the subsurface salinity dissolution and transport processes including the geochemical leaching characteristics of the strata, residence time, and the rate of salt production from unweathered shale. The goal was to assess the feasibility of controlling salinity loading from both geologic and agricultural salt sources at the test field site.

The location selected for detailed investigation lies between Miller Creek, one of the major tributaries of the Price River, and the Carbon Canal. An important result of our study is that in order to understand how salts are mobilized and transported in groundwater, the groundwater flow paths must be mapped in some detail, and that the details of this flow system are primarily controlled by the bedrock topography. Along flow paths the water changes from a carbonate to a sulfate dominated system with depth and distance of travel. Overall, geochemical equilibrium rarely exists because of large concentration gradients.

The transport modeling was performed using an iterative Galerkin-type finite element method to solve the equations of seepage in the saturated-unsaturated porous media under steady-state conditions. A two-dimensional steady-state, advection-dispersion model is combined with the flow

equation to determine solute transport. The salinity transport modeling for this situation showed how the dilution of water in the shallow alluvium aquifer increases the concentration gradient at the alluvium interface and the upward diffusion of salts from the consolidated marine strata below.

#### Application of Research Results

This first step towards a combination of groundwater flow, salinity transport, and geochemical interactions in a single groundwater model provide the starting point for truly scientific design of salinity control measures. The illustrative application to a specific study area provides a practical demonstration of what can be done if the physics of the flow systems are understood. Irrigators, the Bureau of Reclamation, and fish and wildlife interests will all have parts in using the results to protect the quality of the river for downstream users.

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FIELD EVALUATION OF GROUNDWATER SALINITY BUILDUP  
FROM IRRIGATION OF SALINE ALLUVIUM

Abstract

Data are being collected from a heavily instrumented field in the Sevier River Valley to quantify the relative effects of concentration by evapotranspiration and of leaching from saline soils in salt buildup in groundwater so that this information can be used to improve farm water management for salinity control.

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Salts leached from saline sedimentary rocks and the alluvium derived from these rocks are degrading surface and groundwater quality in many arid areas. Under natural conditions, infiltration rates are too small to carry much salt down to the groundwater. With irrigation, the water applied in excess of the crop consumptive use becomes deep percolation and dissolves salts and transports them into the groundwater and eventually into downstream baseflow. Preliminary studies of the alternatives for salinity control in the Price and San Rafael River basins suggest that the most economical way to preserve downstream water quality is to stop irrigation over highly saline subsoils. Before taking such drastic action, it is important to make sure that improved irrigation water management cannot sufficiently reduce the rates of salt build-up. More information is needed on leaching mechanisms and other processes contributing to salinity build-up.

Research Project Accomplishments

The two initial objectives of this study were to 1) design and implement a field sampling program and 2) analyze the data with computer models to examine the salinity build-up associated with various control and alleviation methods. This general objective lead to six specific objectives in data collection and analysis at a field site:

1. Define the characteristics of the groundwater flow system under the root zone.
2. Quantify the irrigation related recharge to the groundwater under the present conditions.
3. Identify the quality and quantity of the creek water that crosses the saline alluvium near the study area.

4. Identify and quantify the sources of salinity in the shallow groundwater underlying the irrigated area and determine how much salt can be ascribed to each concentrating component--leaching and evapotranspiration--compared to the pre-irrigation state.

5. Determine the salinity hazard to downstream landowners and other water users under different levels of upstream irrigation water availability.

6. Recommend management practices for controlling or alleviating salinity build-up in the shallow groundwater and suggest how these practices might apply in other similar areas.

During the summer of 1984, 23 wells were drilled and 8 vadose zone samplers were installed in and around irrigated fields on



the Dastrup property on Brine Creek, near Sigurd, Utah. The measurements obtained from these wells and vadose zone samplers are now being reviewed to determine how the current program can be made more efficient and provide better data. Scattered parameter data--transmissivity, aquifer bottom elevation, aquifer thickness, and initial water elevation--were used to interpolate by the inverse transmissivity method parameter values for each cell of a finite difference grid representing the area. The U.S. Geological Survey program "A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model" is being used to model the groundwater flow. The model has been calibrated for steady-state flow and is now being calibrated for transient flow. A solute transport model has been chosen and adapted for the site, but the transient flow calibration is needed before the solute transport model can be added and calibrated.

Observations from the 23 wells have shown the effect of irrigation on groundwater flow under the fields. Objective 2 is being accomplished by the use of a flow meter in the irrigation pipe supplemented by notes kept by Mr. Dastrup when he irrigates each field. The amount of irrigation that runs off the surface is being monitored intermittently by a Parshall flume. Objective 3 is being accomplished by installation of three Parshall flumes on Brine Creek and by collecting samples of creek water for quality analysis. Objective 4 is being accomplished by vadose zone samplers at 4- and 8-foot depths in the irrigated fields and by soil leaching columns in the laboratory, using the soil from each field and irrigation water is applied to the fields. Objectives 5 and 6 will be accomplished with the computer models after they are calibrated.

The results show that irrigation is changing the groundwater as follows:

1. Most wells show a higher water table and greater salinity in July 1985 than in July 1984.

2. For wells upstream from the irrigated fields, a higher water table generally corresponds to lower salinity. For the wells below the fields (Figure 1, wells 11, 12, 13, 14, and 15), the water table and salinity rise during irrigation, demonstrating that more water of poorer quality is moving down-gradient.

3. The wells in the middle of the fields generally show a higher water table and lower salinity as the irrigation season progresses, an indication that the upper soil layers were leached during previous years and that deep percolation from irrigation may be diluting the more saline groundwater (see Figures 2 and 3).

4. The vadose zone samplers installed at a 4-foot depth generally show a much lower salinity than the vadose zone samplers installed at an 8-foot depth, another indication that the salts have already been leached from the upper soil layers (see Figures 2 and 3).

Other significant findings include the following:

1. In the fields, the salinity in the shallow wells (20 to 40 feet) decreases after irrigation starts. Deeper wells (50 to 70 feet) show little or no change. The vadose zone samplers, at both 4- and 8-foot depths, show no recognizable patterns. With bi-weekly sampling, the time variability in evapotranspiration and the spatial variability in soil conditions and crops in the fields are too large for patterns to appear.

2. After heavy summer thundershowers, the wells showed the downward gradients to be expected as the infiltrated precipitation moves through the soil profile.

3. From July 1984 to January 1985 in Field A, the 55-foot well had water with ECs of less than 1000 mhos/cm compared to ECs of 6000 mhos/cm in the 40-foot well. In March 1985, the quality in the deep well began to degrade. By late May, it was about the same as in the 40-foot well. The water surface in the 55-foot well has been consistently higher than that in the 40-foot well. Field A is the only place where this artesian effect was observed.

#### Application of Research Results

A field level data base is being established to collect and analyze data that can be used to reduce drainage water salinity through improved farm water management. Success will contribute to salinity control around the world.

U.S. Geological Survey  
05/01/83 - 12/31/85  
Research in Progress

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COMPARISON OF DIRECT FILTRATION AND CONVENTIONAL WATER  
TREATMENT SYSTEMS TO REMOVE POLLUTANTS FROM SOURCE WATERS

Abstract

A performance comparison between a direct filtration plant for drinking water treatment and a conventional plant with a sedimentation basin to remove the flocculated materials showed that the direct filtration process performed equally well at reduced cost.

Principal Investigator

V. Dean Adams (PhD), Organic Chemistry

Support Personnel

Ronald C. Sims (PhD), Environmental Engineering

Student Assistants

Susan Burns (BS), Civil and Environmental Engineering

Steel Maloney (BS), Watershed Science

In June 1977, the U. S. Environmental Protection Agency revised the National Interim Primary Drinking Water Regulations to lower the maximum permissible turbidity level from 5 to 1 turbidity units (TU). Many communities that previously only disinfected their drinking water are now required to remove particulate matter. Many of these are now searching for inexpensive treatment systems that can achieve the new standard.

A direct filtration is a water treatment system in which the filtration is not preceded by sedimentation of the flocculated water. The treatment system can contain flocculation or contact basins as long as sedimentation is not provided before filtration. Direct filtration with sand filters was tried in the early 1900s but proved unsatisfactory because the filters quickly became clogged. However, the alternative largely used over the last 60 years of chemical flocculation followed by sedimentation requires an expensive settling basin that becomes increasingly costly as greater removal requirements necessitate longer detention times. Compared to conventional treatment, direct filtration has lower capital costs, reduced space requirements, smaller sludge quantities, and reduced chemical costs.

In the last 20 years, coarse-to-fine dual- and mixed-media filters have been developed that can remove the floc without excessive head loss, but their effectiveness in removing pathogens and potentially toxic organic compounds requires further evaluation. This study examined the effectiveness of direct filtration in satisfying the Utah and National Interim Primary Drinking Water Regulations through a literature review and a performance analysis of a Utah plant. The Utah Department of Health, Division of Environmental Health, is interested in searching out low-cost treatment facilities, appropriate for the Intermountain area. In the face of growing numbers of direct filtration plants, they are particularly interested in performance evaluations of their effectiveness. The approach used here was to select parameters for analyzing the "quality of the product" and apply them in evaluating the direct filtration facility at Orem.

## Research Project Accomplishments

Assessment of the effectiveness of direct filtration involves comparisons of its performance with that of conventional systems and the required water quality standards. As long as the standards are met, the treatment process is acceptable; but a significant difference between the performances of the two processes, even when both are well within the acceptable levels, indicates that the one performing less well will be acceptable for treating a narrower range of raw water qualities and will be less satisfactory should even stricter standards be adopted in the future.

The assessment performed for this study compared the quality of the product water produced by direct filtration at the Utah Valley plant with that produced by a conventional treatment facility, the Little Cottonwood Metropolitan Water Treatment Plant at Salt Lake City. These treatment plants were chosen for comparison because they used the different processes but treat a similar source water.

Daily water quality and plant operation log sheets from August 1, 1980, through August 31, 1983, were obtained for both the Utah Valley and Little Cottonwood Treatment Plants. The eight parameters chosen for comparison were total daily flow, raw water turbidity, effluent turbidity, effluent chlorine residual, raw water pH, effluent pH, finished water temperature, and alum dosing concentrations. The most important parameter for this investigation is finished water turbidity. The mean

finished water turbidity for both the Utah Valley Water Purification Plant and the Little Cottonwood Metropolitan Treatment Plant were well below the EPA Primary Drinking Water Regulation of a maximum contaminant level of 1 TU.

The randomized block design analysis indicated no significant difference between the finished water turbidities for the Little Cottonwood Treatment Plant and the Utah Valley Water Treatment Plant. All the other parameters investigated in the analysis of variance showed significant differences but no problems affecting treatment reliability.

## Application of Research Results

The statistical analysis showed that the direct filtration process at the Utah Valley Purification Plant produces an acceptable quality of water and one that is comparable in quality to that of the conventional sedimentation processes of the Little Cottonwood Metropolitan Treatment Plant. Within the limits identified in the literature review, direct filtration performs satisfactorily in turbidity removal. These and other study results provide data that engineers can use in designing these plants and that regulatory agencies can use in overseeing their applications.

U.S. Geological Survey Cooperative Program  
07/01/83 - 09/30/84  
Research Completed

## Publications

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(Article for professional journal in preparation.)

TOXICITY AND ENVIRONMENTAL HEALTH HAZARDS OF PETROLEUM  
PRODUCTS IN WELLS USED FOR DRINKING WATER IN THE  
INTERMOUNTAIN WEST

Abstract

The contamination of well water by petroleum products leaking from underground storage tanks is causing increasing concern, and an effort is underway to characterize the resulting types and concentrations of petroleum products in groundwater and exposure of humans to toxic effects (e.g., immunologic and neurotoxic).

Principal Investigators

Robert D.R. Parker (PhD), Environmental Health  
Raghubir P. Sharma (PhD), Toxicology  
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Support Personnel

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Student Assistant

Gin-Chang Hsieh (MVM), Environmental Toxicology

Groundwater is a primary source of drinking water for about one-half of the U.S. population. Leaks of petroleum products from leaking underground storage tanks (LUST) at industrial plants, commercial establishments, and other operations could be expected to increase the types and concentrations of petroleum products in groundwater used for drinking and exposure of humans to the toxic effects of these chemical compounds. Contamination of well water by petroleum products from LUST is a matter of increasing concern. Petroleum products are persistent and highly mobile contaminants which are difficult to remove from groundwater. In addition, many of these chemicals are known or suspected carcinogens or mutagens which can pose undesirable effects on human health at very low concentrations (<10 ppb). There is a need for conducting more research on the types and concentrations of petroleum products found in wells used for drinking water and the toxic effects (immunologic and neurotoxic) of these chemicals.

Leaks of petroleum products from underground storage tanks in the U.S. pose a serious threat to public health and the environment. This project will provide information on types and amounts of volatile and nonvolatile petroleum products in groundwater and toxic effects of selected petroleum contaminants (e.g., benzene, toluene, phenol) in laboratory animals (CD-1 mice).

Research Project Accomplishments

Preliminary water samples were obtained in September 1985 from three shallow wells (12-14 feet deep) and one deeper well spread out over an area extending from north Salt Lake City (about 3100 N 2500 W) to Sandy, Utah (about 9000 S 700 W). The wells were located in the vicinity of industrial plants or gasoline stations.

After purging each well by evacuating a minimum of 3 well casing volumes, water samples for volatile organic pollutant analysis were collected with a clean Teflon bailer and carefully put into 100 ml borosilicate amber glass bottles with Teflon septa and screw caps. Grab samples for nonvolatile organic pollutants were obtained with a clean 5-gallon stainless steel bucket previously filled to about two-thirds capacity with the

bailer and poured with a clean stainless steel cup into 1 liter glass bottles which were then covered with aluminum foil. The samples, collected in duplicate or triplicate, were packed in an inverted position in coolers with blue ice packs for return to the Utah Water Research Laboratory. At the laboratory, samples were stored at 4°C for later chemical analysis. Temperature, pH, and conductance of water samples collected in the field were measured and recorded. All sampling equipment that would be in contact with well water was rinsed with acetone, and double distilled water, with a final rinse of well water before use. All water samples collected during the month of September have been processed and are waiting for final analysis by GC/MS. Results of the characterization of petroleum contaminants in the well water samples will be available before the end of October 1985.

Experiments were conducted to determine the effects of benzene on the immune and nervous systems in mice. Male, adult CD-1 mice were continuously fed drinking water ad. Lib. containing 0, 40, 200, and 1000 ppm benzene for a 4-week period. Food, water consumption, and individual body weights were recorded throughout the experimental period.

After 4 weeks of treatment, five mice from the control and each of the test groups were killed by decapitation and their brains quickly dissected into six anatomic regions (hypothalamus, cerebellum, medulla oblongata, midbrain, corpus striatum and cortex) and frozen for later analysis. These brain regions will be analyzed by high pressure liquid chromatography (HPLC) for major biogenic brain amines (e.g., dopamine, norepinephrine, and serotonin) to determine possible changes in the levels of neurotransmitters that control behavior. No abnormal behavioral effects indicative of neurological alterations were observed in any of the test animals during the study period.

At the end of the 4th week, five additional mice from the control and each of the test groups were killed by decapitation and their spleens removed. Splenic lymphocytes were separated and cultured with various mitogenic agents; concanavalin A (Con A), phytohemagglutinin (PHA), pokeweed mitogen (PWM) and lipopolysaccharide (LPS) which are good indicators of the various populations of lymphocytes, the cells important in immunocompetence. In addition, the splenic lymphocytes were evaluated in mixed lymphocyte cultures (MLC) and for cytotoxic cells. Five

mice from each group were also injected with sheep red blood cells (SRBC) after 4 weeks of treatment. Splenic cells were collected from these animals to determine anti-SRBC antibody response by enumerating plaque-forming cells (PFC) and by determination of specific hemolysis by enzyme linked immunosorbent assay (ELISHA). Blood cell counts and relative weights of organs (spleen, kidney, liver and thymus) for each animal were recorded.

Continuous exposure of mice to drinking water containing 40, 200, and 1000 ppm benzene for 4 weeks had no significant effect on food consumption or on body weights. Drinking water consumption decreased only slightly. At the 200 and 1000 ppm levels, there was a noticeable increase in kidney weight and a decrease in red blood cell (RBC) count of exposed animals when compared to controls. In addition, the uptake of <sup>3</sup>H-thymidine by the splenic lymphocytes of the exposed animals cultured with various mitogens and in mixed lymphocyte culture was significantly suppressed. However, at 40 ppm level, the uptake of <sup>3</sup>H-thymidine by splenic lymphocytes was enhanced. The results of the <sup>51</sup>Cr-release assay show that cell-mediated cytotoxic T-lymphocyte response against <sup>51</sup>Cr-labelled tumor cells is moderately effected by benzene exposure. Antibody production, assessed by the number of plaque forming cells (PFC) was depressed in animals exposed to 1000 ppm and stimulated in mice exposed to 40 ppm. In general, the results indicate that after 4 weeks of continuous exposure to drinking water containing certain concentrations of benzene CD-1 male, adult mice are susceptible to immunotoxic effects.

#### Application of Research Results

Since this new research project was approved and initiated on June 25, 1985, it has been in effect approximately 3 months and since no data have been published no one has been able to use the results achieved by September 30, 1985. It is anticipated that various water quality and toxicology groups or agencies (e.g., State Health Department, petroleum refining industries, chemical manufacturers, EPA, USGS, universities, etc.) will be able to use the results produced by this project.

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USDA/USGS  
06/25/85 - 06/30/86  
Research in Progress

PROTECTION OF GROUNDWATER BY IMMOBILIZATION OF HAZARDOUS  
METALS ASSOCIATED WITH INDUSTRIAL WASTES IN  
LAND SYSTEMS

Abstract

Laboratory studies are being combined with computer modeling to quantify rates of toxic metal retention in soil systems under varying conditions as an aid in the selection of soil amendments for the immobilization of metals near the soil surface thus protecting groundwater from metal pollution.

Principal Investigators

Ronald C. Sims (PhD), Environmental Engineering  
Joan E. McLean (MS), Soil Chemistry  
Judith L. Sims (MS), Soil Science  
Christopher J. Duffy (PhD), Groundwater Hydrology  
Lynn M. Dudley (PhD), Soil Chemistry

Support Personnel

David C. Lentz (BS), Zoology

Student Assistant

I-Fu Shen (BS), Civil Engineering

Land farming of industrial wastes as well as landfills may pose a serious threat to groundwater quality due to migration of toxic metals through the unsaturated soil zone into the groundwater. Metal-soil interactions are such that an accumulation of metals normally occurs at the soil surface. The physical and chemical processes in soils that retain metals against downward movement may, however, be exhausted by the high levels of metals associated with some industrial wastes. Toxic metals, because of their resistance to detoxification and degradation, pose a long-term threat to groundwater quality. This threat can be reduced considerably if the metals can be immobilized in the upper soil horizons.

Research Project Accomplishments

The objective of this study is to evaluate soil-waste interactions and the use of soil amendments (i.e., pH-adjustment, activated carbon, and agricultural by-products) for immobilizing metal constituents in industrial waste samples from the Intermountain West. The ultimate objective is the assurance of groundwater quality for protection of public health and the environment. The approach for in-situ treatment is to utilize fundamentals of soil chemistry and physics (i.e. sorption/precipitation) to control both the extent and the rate of movement of toxic metals in land systems. Ideally, treatment techniques will be developed that will reduce the aqueous concentration of metals to essentially zero, resulting in a leaching rate from the site at an acceptable public health risk level within the context of risk assessment and risk management.

A waste characterization scheme was developed to define the leaching potential of metals in each waste. Using waste leachate, batch sorption studies were performed to determine waste-soil interactions and define the metal attenuation capacity of the soils. Results of laboratory studies, with the aid of GEOCHEM, a soil chemical thermodynamic computers program, indicated that exchange reactions and precipitation were the dominant solid phases controlling copper solution chemistry. The two soils used have a large attenuation capacity for copper. The soils are both alkaline and contain calcium carbonate. The high pH and the presence of carbonate allows for sorption and precipitation of copper in these soil systems. Other cationic metals in the waste (presently under investigation) are expected to behave similarly.

Because of the direct influence of pH in metal solution chemistry, waste leachate pH

and soil buffering capacity were the dominant factors affecting soil attenuation capacity. Amendments that modify leachate pH and that contribute sorption sites to the soil are anticipated to be most effective in retaining metals. The model GEOCHEM along with laboratory column leaching studies will be used to evaluate the effectiveness of the various proposed treatment techniques.

#### Application of Research Results

This research will demonstrate whether treatment techniques investigated are effective for treatment of wastes containing inorganic constituents. Industries and uncontrolled hazardous waste sites identified as sources of these wastes will receive land treatment criteria from this study. Information concerning the leaching/sorption potential of metal constituents will be directly

applicable for determination of effectiveness of terrestrial systems as a treatment/barrier for the protection of groundwater. Protection of groundwater sources in the water-scarce Intermountain West is vitally important in any waste management scheme for the treatment/disposal of hazardous wastes. Results to date have been used by the Utah Bureau of Solid and Hazardous Waste for assessment of potential groundwater pollution at the various uncontrolled hazardous waste sites.

U.S. Geological Survey Cooperative Program  
06/01/85 - 05/31/86  
Research in Progress

#### Publications

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McLean, J. E., R. C. Sims, and J. L. Sims. 1985. Immobilization of hazardous metals associated with industrial wastes in land systems. National Specialty Conference on Land Treatment: A Hazardous Waste Management Alternative, U.S. Environmental Protection Agency, Austin, Texas.

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THE USE OF STRUCTURE-ACTIVITY RELATIONSHIPS AS AN AID IN  
MODELING THE SUBSURFACE TRANSPORT OF ORGANIC CONTAMINANTS

Abstract

This study will develop and evaluate the use of Structure-Activity Relationships (SARs) in estimating important parameters required to model the chemical transformations of organic contaminants transported through subsurface systems. The use of SARs, relating the behavior of a chemical to its structure, can greatly simplify estimation. However, initially laboratory methods for measuring these parameters will also be employed to provide the necessary data.

Principal Investigators

William J. Doucette (PhD), Water Chemistry  
Ronald C. Sims (PhD), Environmental Engineering  
R. Ryan Dupont (PhD), Environmental Health Engineering

Statement of Water Problem

Protection of the quality of groundwater and surface water resources is becoming increasingly important as the Intermountain West becomes more industrialized. The State of Utah, alone, has eight "superfund" sites and one hazardous waste disposal facility. With the growing number of hazardous waste sites, the potential for accidental release of toxic organic contaminants into subsurface water systems is increasing. Regulatory agencies and industries managing hazardous wastes and hazardous waste disposal sites require methods to estimate the mobility of organic contaminants in the subsurface systems that may impact both groundwater and surface water resources.

Mathematical models, which attempt to integrate the variety of physical, chemical, and biological processes taking place in the subsurface systems, offer a promising approach to predicting the transport of contaminants. These models require input parameters quantifying site, soil, and contaminant physico-chemical and biological characteristics. One major limitation to the use of such models is the lack of reliable estimates of the required input parameters. While soil and site characteristics are easily determined using standard techniques, quantitative estimates of contaminant properties are difficult to measure experimentally, especially considering the large number of organic compounds that can be spilled into the natural environment. Until practical methods for estimating the many necessary parameters are developed, applications of the models to predict subsurface transport for the multitude of contaminants present in hazardous wastes will be severely restricted.

Results and Benefits

This research project is developing and evaluating the use of structure-activity relationships (SARs) in estimating several important parameters required to model the transport of organic contaminants. Laboratory methods for obtaining these parameters will provide data necessary for

development of SARs. Structure-Activity Relationships which attempt to relate the structure of a chemical to its behavior, have been widely used in pharmaceutical industries to predict the transport and partitioning of organic drugs in biological systems. Extension of these principles for application to groundwater transport will provide a comprehensive methodology for generating information that can be used to evaluate the suitability of a site for hazardous waste disposal. The estimates as well as the methodology, will be made available to state and federal government divisions in the Intermountain West involved with hazardous waste management. Both the the U.S. Environmental Protection Agency and the American Petroleum Institute have expressed specific interest in the use of SARs for generating information required to evaluate proposed alternatives for groundwater protection from hazardous organic chemicals. This information could also be used by industries evaluating or disposing of hazardous wastes.

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USGS

April 1986 - June 1987

Reserch In Progress

1981 SYMPOSIUM ON THE AQUATIC RESOURCES MANAGEMENT OF THE  
COLORADO RIVER ECOSYSTEM

Abstract

A symposium on the aquatic resources of the Colorado River provided opportunity for exchange among scientists and agency personnel responsible for reservoir operation on any operation changes desirable to protect aquatic resources and research needed to support management goals.

Principal Investigator(s)

Vincent A. Lamarra (PhD), Limnology  
V. Dean Adams (PhD), Organic Chemistry

The reservoirs on the Colorado River have been operated for water supply, hydroelectric power, and flood control with only incidental thought as to effects on the aquatic resources associated with the river and lake ecosystem. Recent environmental concerns are, however, placing increased emphasis on the need to protect or enhance viable biological communities within these rivers and lakes for purposes of water quality control, recreation, aesthetics, and preserving the intrinsic values of these ecological communities. In order to provide for this need, one must understand how alternative river control policies affect the ecosystem. Studies are beginning to collect pieces of needed information, but interaction is needed among the investigators to be able to put the pieces together in understanding the aquatic systems.

Research Project Accomplishments

A symposium on the Aquatic Resource Management of the Colorado River Ecosystem was held in Las Vegas, Nevada, on November 16-19, 1981. The conference provided a forum for information exchange to enhance determination of what can be done to better manage the aquatic resources of this important river system. The conference involved people with river management responsibility and research scientists in making and discussing 44 oral presentations, and the papers will be published in a proceedings. The last session was a panel discussion by representatives of the major disciplines covered during the conference that provided opportunity for dialogue on coordination opportunities and research priorities.

The major areas covered during the three-day conference were:

1. Present and potential impacts of energy resource developments and new energy use technologies.

2. Major reservoirs (flow regulation, sedimentation, evaporation, salinity, trophic status, etc.).

3. Interbasin water transfers with their associated legal aspects and potential impacts on water quality (salinity, flow depletion, water diversions, etc.).

4. Land use and basin developments as they affect groundwater and overland flow to the reservoirs and inter-reservoir systems. Changes to water, groundwater interactions, agricultural runoff, and other factors that change flow patterns, and water quality impacts of the ambient flora and fauna of the river system.

5. Collective effects of water and land use practices (reservoirs, salinity control projects, with transfers from agriculture to energy, etc.) in the Upper Basin and the Lower Basin. What negative and positive effects actually occur from upstream management?

Application of Research Results

The symposium initiated interactions among scientists and agencies and stimulated research ideas that will contribute to evolution of effective river control policy enhancing both the benefits of water use and aquatic resource protection.

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Office of Water Research and Technology  
through the University of North Carolina  
Water Resources Research Institute No.  
0518-23, and the Utah Water Research Labora-  
tory, 12/01/80 - 12/31/81, Research Com-  
pleted.

#### Publications

Adams, V. D., and V. A. Lamarra. 1982. Aquatic resources  
management of the Colorado River ecosystem. Ann Arbor Scien-  
ce, Ann Arbor, Michigan.

# THE EFFECTS OF DROUGHT ON THE ALLOCATION OF WATER BETWEEN AGRICULTURE AND ENERGY CONSIDERING INSTREAM USES

## Abstract

Identification of the effects of drought on water allocation between diversions and instream flow uses are being incorporated into a stochastic optimization model for estimating stream recreation and other inflow requirements and evaluating policies for achieving them.

### Principal Investigator(s)

Rangesan Narayanan (PhD), Economics  
David S. Bowles (PhD), Civil Engineering  
L. Douglas James (PhD), Civil Engineering

### Student Assistant(s)

Parvaneh Amirfathi (MS), Economics

Concern with regard to the preservation of instream values has increased with the substantial growth in demand for water for offstream uses. Market systems alone cannot be expected to resolve this conflict through the price mechanism due to the "public good" nature of instream flows. For any given flow, many different instream activities can take place simultaneously. Criteria are needed to determine needs for instream flow. Methodology is needed to assess the relative costs of maintaining instream flows using alternate strategies. Consideration of the variability in stream flows is also important in the arid climate of the western states as it introduces uncertainty both in benefits and costs of instream flow maintenance. Strategies are needed to maintain instream flows consistent with the legal and institutional framework.

The demand curve can be derived for specific instream activities. In case of conflicts interdependencies can be accounted for in the demands by adding or subtracting the marginal effects of one activity on others. The aggregate demand for instream flows is obtained by vertically summing all the demand curves. The supply curve of water for instream flows can be derived as a residual by subtracting offstream demand from the marginal cost of water. The residual supply curve reflects the resource cost of maintaining instream flow, whether the cost is through foregone benefits in present offstream uses or for water supply augmentation such as additional groundwater pumping. The intersection of this residual supply curve with the instream flow demand determines the efficient allocation of water.

This sort of cost-benefit analysis is complicated when uncertainty with respect to water availability is introduced. Difficulties in establishing criteria and definition of benefits, lack of benefit estimation techniques, and scarcity of site specific data are the obstacles. A simpler alternative for dealing with instream flow requirements under uncertainty is to assess the expected costs of meeting a given "expected instream flow requirement" under alternate strategies.

### Research Project Accomplishments

A general stochastic linear programming model has been developed to estimate the costs of alternative levels of expected instream flow requirements under different strategies. These strategies include 1) purchases of water rights of appropriate

priorities by a government agency and 2) statutory minimum flow reservations. Under the first option, analyses have been carried out with and without short-term water rights transactions. Strict application of expected instream flow criteria may not provide sufficient instream flows under low flow

conditions. Therefore, the approach is modified to include a critical instantaneous low flow to prevent irreversible ecological damage.

In order to determine the instream flows that will maximize the excess of expected benefits over costs, an econometric model of recreation demand was formulated. The data for estimating a system of demand equations involving substitution between recreation sites and activities are being compiled.

The model was applied to the Little Bear-Blacksmith Fork drainage in Cache County, Utah. To provide satisfactory fishing, the expected reduction in the value of agricultural output would be about 40 percent.

Decision rules for optimal allocation of water between offstream uses and instream flows were derived using travel-cost approach. Instream flow demand functions were then determined based upon weak complementarity principles.

#### Application of Research Results

The overall conclusion that the minimum flow reservations adopted in many western states for instream flows are costly should lead toward more reasonable programs. Other alternatives, such as holding a combination of both senior and junior water rights for instream flows, seem to offer promise. The results indicate that the instream flow benefits attributable to recreation on an average flow year is between \$8,000 to \$16,000. Depletions for offstream uses for 60 percent exceedance flows will have negligible effect on recreation.

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Agreement No. A-052, 14-34-0001-1147, 10/01/  
80 - 03/31/83, Research Completed, FCCSET  
Category: VI-B.

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DEFINING STREAM FISH MICROHABITAT REQUIREMENTS  
FOR WATER PROJECT PLANNING

Abstract

The physical characteristics of a reach of the Blacksmith Fork River were measured and correlated with the locations where brown trout are found for the purpose of defining habitat requirements for use by engineers in designing water management schemes that do not create undue environmental harm.

Principal Investigator(s)

William T. Helm (PhD), Fisheries and Wildlife

Support Personnel

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Richard H. Hawkins (PhD), Watershed Science  
Jeff Kehoe (BS), Zoology  
Tom Annear (MS), Fisheries and Wildlife

Student Assistant(s)

Tim Martin (BS), Electrical Engineering	Joel P. Bich (BS), Wildlife Science
Terry Lee (BS), Fisheries and Wildlife	Ken Bickel (BS), Wildlife Science

Water resources development changes flow regimes, channel configuration, and the productivity of stream habitats. Construction may denude stream banks of vegetation, eliminate vertical and horizontal sinuosity, change heterogeneous substrate to one of a more uniform size and structure, and generally reduce the diversity of habitat within a stream system. Fish populations are known to depend on these physical characteristics, but specific information on how productivity varies with particular physical perturbations is not available for use in protecting fish habitat against stream alterations. For example, the habitat specifications for such important stream fishes as the brown trout (*Salmo trutta*) are described in such general terms as good cover, moderate current, and adequate depth. This project is designed to develop more precise statements of habitat requirements and preferences for this species and thereby provide specifications for preserving instream flow uses.

Research Project Accomplishments

The stream reach used for habitat analysis was a 100-meter portion of the Blacksmith Fork River above Cache Valley, Utah. The stream has a good diversity of habitat and a substantial brown trout population. The physical microhabitat components of light, current velocity, depth, and substrate size were measured at points spaced every 0.5 meter across the stream on transects located every 2 meters along the length of the stream. The measurements were used to construct a map for each component.

Component data on the maps were correlated with observed fish locations.

Scuba observation was used to determine the brown trout distribution within the mapped area. Most brown trout were observed in locations where physical habitat features fell within the range generally recognized as usable. Few fish were found in velocities above 1.5 fps (the upper usable limit), but some were found in full sunlight (a location previously believed not usable). Larger fish usually remained close to bottom, even when feeding, while juveniles were often observed

close to the surface feeding on floating insects. Current velocity appears to be the most important factor determining brown trout habitat, with light and depth also influential for certain sizes of fish and certain activities.

Observations from a tower on the stream bank provided information on the distribution of fish in water too shallow for scuba operation. In good habitat where trout can rest in areas of subdued light under brush, behind rocks or on the bottom of deep pools, tower observations may miss a large proportion of the fish occupying resting habitat. During such activities as feeding, however, a much larger proportion of the population are visible from locations above the water surface.

Investigations of the light spectrum in an experimental tank were used to explore the effects of certain wavelengths on trout distributions. The brown trout avoided areas of bright ultraviolet light as well as bright visible light and consistently positioned themselves in the lowest light levels. When the area of highest light intensity, whether ultraviolet or visible light, was less than about 2 percent of maximum natural light intensity, the fish no longer displayed any avoidance reaction.

#### Application of Research Results

With the characteristics of good brown trout habitat known, engineers can do a better job of protecting stream environments from changes caused by water project development or management practice alterations. A water project that may generate economic gain will not have to be delayed, interrupted, or

abandoned because of the inability to be sure that no irreparable environmental harm will occur. The quantitative habitat descriptions developed through this research can be used by the many federal and state agencies and private organizations that have responsibilities for planning and implementing water projects.

Concepts developed during the research are already being applied in two Utah projects. A highway construction project in southern Utah is relocating portions of a trout stream. Utah Division of Wildlife Resources personnel have worked with Department of Highways engineers to design channel changes to provide a desirable habitat. Evaluations of small hydropower projects in Utah are also conducted utilizing habitat measurements and data similar to those developed by this project.

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Office of Water Research and Technology,  
Agreement No. B-177, 14-34-0001-9140,  
01/01/79 - 12/31/81, Research Completed,  
FCCSET Category: VI-G

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Helm W. T., J. C. Goose, and J. Bich. 1982. Life history, microhabitat and habitat evaluation systems. Proceedings of the SYmposium on Acquisition and Utilization of aquatic Habitat Inventory Information. American Fisheries Society.

(Three presentations were made at professional meetings.)



# THE EFFECT OF RISK OF DROUGHT IN ENERGY DEVELOPMENT AND WATER ALLOCATION: A PROGRAMMING MODEL FOR UTAH

## Abstract

A chance-constrained separable programming model was used to determine how the variability of water availability affects the optimal allocation of water between energy production and agriculture and thereby the effects of energy development on water availability to agriculture during droughts.

### Principal Investigator(s)

John E. Keith (PhD), Economics  
Terrence Glover (PhD), Economics  
Herbert H. Fullerton (PhD), Economics

### Student

Gust Gertsel (MS)

Past examinations of the impact of meeting the water requirements for development of Utah's energy resources on prior agricultural uses found little conflict in average flow years. The significant conflicts occur during drought years. Possible action plans include using reservoirs for water storage, temporary groundwater mining, and reduction in water allocations to less valuable uses. From information on the optimal allocations of water, given drought probabilities, water allocations between agriculture and energy can be more meaningfully monitored and proposed measures for water supply augmentation can be more accurately evaluated.

The linear programming models used to allocate available water among user sectors assume fixed-coefficient production functions; that is, each unit of output requires a specified number of units of each input. In an actual production process, uncertainty may cause substitution between inputs for given levels of output, and the level of output may vary from what would occur in the certainty case. The wide range of possible responses varies between 1) acquiring a large amount of the reliable factor (perhaps land) so as to be able to exploit any supply of the variable factor, and 2) acquiring a large amount of the variable factor so as to make it a virtual certainty to be able to use all of the reliable factor. Clearly, the two extremes bound a wide range of allocations for water, the variable factor, between agricultural users and energy developments. The water used for a particular purpose will depend upon the price of water relative to other inputs and the fluctuations in water availability. Accurate assessment of the effects of energy development on other water uses thus requires analysis of the variability as well as of the amount of available water.

### Research Project Accomplishments

A chance-constrained separable programming model of water allocations between agriculture and energy production was developed in order to examine the effect of the variability of water supplies in Utah. Using an incomplete gamma function, fit to historical flows by the method of moments, the water amounts available with 85, 90, and 95 percent probabilities were estimated and used as constraints in the allocation model. Results indicate that water quality problems may be even more severe than water shortage problems and be a greater constraint on irrigated agriculture in the face of large scale energy development. The variability of water availability is not likely to be a significant factor constraining economic growth in Utah.

### Application of Research Results

The model provides a quantitative basis for assessing the effects of drought on the availability of water for energy development and for Utah agriculture. This information can in turn make an important contribution to water management where allocations between agricultural and energy uses are important.

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Office of Water Research and Technology,  
Agreement No. B-182, 14-34-0001-9141, 10/01/  
79 - 03/31/82, Research Completed, FCCSET  
Category: VI-A

Publications

Keith, J. E., G. A. Martinez-Gerstl, R. Narayanan, and D. L. Snyder. 1982. A chance-constrained programming model of water allocations in Utah. UWRL/P-92/06. Utah State University, Logan, Utah.

(Article in preparation.)

ADAPTING WESTERN WATER LAW TO ACCOMMODATE EQUITABLE  
CONSIDERATION OF INSTREAM FLOW USES

Abstract

An examination of the water codes in the prior appropriation states showed that public interest provisions can be used to protect instream flow, but that poorly defined instream values and the difficulty in revising formalized allocations are impeding the progress.

Principal Investigator(s)

Jay M. Bagley (PhD), Civil Engineering  
Dean T. Larson (MS), Political Science

Support Personnel

Lee Kapaloski, Attorney at Law

Growing interest in the protection and enhancement of values associated with naturally flowing streams suggests that such uses deserve legal recognition on an equal footing with other legitimate uses. Yet, the appropriation system of water rights, employed exclusively in the Rocky Mountain states, has been criticized as being incapable of accommodating instream flow uses on an equitable basis. Assessment of the problem requires that impediments to the equitable accommodation of instream flow uses be identified and carefully evaluated in the contexts of associated hydrologic realities, political strategies for protection, and the sound legal principles of resource use. Such an evaluation should be anchored in the notion that both instream and out-of-stream uses have high social utility and the preemptive protection of particular uses may limit adaptability to changing social priorities over time.

Research Project Accomplishments

A set of criteria whose embodiment in state water law would assure equitable treatment of all water uses has been defined. A comparative analysis of the present state water codes of Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming with respect to the model criteria was accomplished. Legislative, judicial, and administrative strategies for protecting instream flows apart from the appropriative system have also been examined.

In general, the appropriation system has the features needed to protect instream flow uses. Specific provisions permit subordinating private rights and exercising governmental authority to make reservations, withdrawals, or condemnations in the public interest. In the absence of a legislative mandate, however, the appropriation system does not give a preference or preemptive status to environmental values over non-environmental ones. The apprehension that instream flow reservations might preempt other rights and/or constrain their latent

opportunity to change points of diversion, place, and nature of use is a basis for concern among those who resist recognition of instream flow rights. A parallel apprehension is that reservations for instream uses become very difficult to change. Insulated from the market process as an indicator of social preferences as needs change over time, a governmental reservation may impose social costs by precluding other public and private water use potentials. For these reasons, water administrators move very cautiously in making reservations or withdrawals.

Another impediment to the integration/recognition of instream flow uses in the appropriation process is the lack of reliable information that relates incremental changes in flow regime to effects on stream habitat and biologic viability. State water administrators must 1) justify quantities of water allocated to any purpose and 2) understand the implications of a particular use (or change in use) on all other water right holders. Water rights administrators are understandably leery of highly empirical methodologies for predicting impacts. As methodologies for assess-

ing impacts and tradeoffs improve, reluctance to recognize rights for instream flow purposes will diminish.

While most states recognize instream flow uses as "beneficial," many still require an actual diversion of water for a bona fide appropriation. Until such transparent reasons for rendering instream flow appropriations invalid are removed, instream flow protection must be sought as public good dependent on the governmental reservation provisions of appropriation law. Innovative uses of market transfers for obtaining instream flow protections and/or enhancements fits the basic construct of appropriation law. As technicalities preventing private appropriation of instream flow uses are removed, the initiation

of private sector strategies for obtaining instream flow allocations will expand.

#### Application of Research Results

The findings of this study should provide water rights administrators, instream flow advocates, legislators, and planners with objective information on methods for legal protection of instream flow rights in prior appropriation states.

Office of Water Research and Technology,  
Agreement No. B-189, 14-34-0001-0279,  
01/01/80 - 12/31/82, Research Completed,  
FCCSET Category: VI-E

#### Publications

Bagley, J. M., D. T. Larson, and L. Kaposloski. 1983. Adapting appropriation water law to accommodate equitable considerations of instream flow uses. UWRL/P-83/06, Utah State University, Logan, Utah.

(Paper presented at ASCE conference.)

AN ANALYSIS OF IMPEDIMENTS TO LOCAL GOVERNMENTAL  
REORGANIZATION/CONSOLIDATION CAUSED BY  
WATER INSTITUTIONS

Abstract

The 1975 and 1978 elections for governmental consolidation in Salt Lake County were analyzed to determine the extent to which water issues influenced voting for or against consolidation and to evaluate the balance between areawide efficiency and local autonomy in urban water management.

Principal Investigator(s)

Jay M. Bagley (PhD), Civil Engineering  
Calvin W. Hiibner (PhD), Political Science  
Dean T. Larson (MS), Political Science  
Kirk R. Kimball (MS), Political Science

Urbanizing areas throughout the nation are examining governmental reorganization or consolidation to overcome problems caused by fragmented planning, administration, and delivery of public services. Growing metropolitan regions invariably experience increasing disparities in quality of services; in tax burdens imposed; and in leadership exercised. The desire to achieve more efficient ways of providing such services over metropolitan areas leads to consideration of numerous coordinating methods of governmental reorganization or consolidation.

Although not always drawing the political attention given to schools and police and fire protection, problems associated with water supply and wastewater services may turn out to be critical. Water entities are diverse in size, function, and operating mode. Each water supply entity has its own water rights developed from a variety of self financed and operated surface and/or groundwater sources. Ofttimes these basic sources are augmented by contractual purchases from water wholesaling entities. Wastewater treatment is normally handled by an entirely different organization. The number of water and wastewater management organizations existing side by side in metropolitan areas have different levels of indebtedness, different combinations of rate charges and taxing structures, and varying capital facilities values. Laws governing their formation, dissolution, and public accountability vary. Elimination of the barriers caused by these differences to efficient water supply services is necessary if water institutions are not to become serious constraints to reorganization and other efforts to improve governmental efficiency.

Research Project Accomplishments

The incorporated communities and unincorporated areas of Salt Lake County experienced unsuccessful governmental consolidation attempts in 1975 and 1978. Leading proponents and opponents of these initiatives were interviewed to obtain their impressions concerning the extent that water considerations may have influenced voter decisions. These discussions with water managers and elected and appointed officials in Salt Lake County identified several water related factors that may have impeded these consolidation attempts.

Leaders of water organizations in Salt Lake County were opposed to reorganization proposals. The proposed reorganization could not spell out in advance how the operations of the many water service organizations would be affected nor how their specific collaborative arrangements might be altered. This lack of specificity created uncertainties which made water managers uneasy. They were concerned as to whether the unification might disrupt a set of water service relationships that had functioned quite well over the years. Those municipalities not initially included in the merger proposal were concerned about future

entitlements and possible loss of equity interests in water rights and distribution facilities they had come to rely on.

Historical patterns of growth have made local water systems preferable to regional water systems in Salt Lake County. However, the advent of regional water organizations such as the Salt Lake County Water Conservancy District has provided some regional economies and pursued areawide solutions to water supply problems which retail distributors have found attractive. Thus, some of the advantages of areawide management have already been obtained while local autonomy has been preserved. The expected gains through governmental restructuring did not appear sufficiently substantial to offset possible interruptions in large water project commitments, added jeopardy to investments already made, and threats to local autonomy in the control of water services.

Many were concerned that governmental consolidation could unsettle the financial underpinning of the Central Utah Project, and this feeling seems to have been a root cause for marshalling opposition to unification by

the water industry. This consideration was not prominently advanced, and few people really understood it as a motivation for water leaders who became active in the opposition. Although water issues were not prominent, the access of the water interests to every household provided an extremely useful information transfer mechanism to present water issues generated by the proposed consolidation and to amplify other points that argued against unification.

#### Application of Research Results

Public officials, water industry administrators, and members of the public at large will benefit from this evaluation of the relationship between the efficiency of water supply services and general government organization and how perceptions of that relationship affect consolidation politics.

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Office of Water Research and Technology,  
Agreement No. B-208, 14-34-0001-1272, 10/01/  
80 - 09/30/82, Research Completed, FCCSET  
Category:VI-E

#### Publications

Larson, D. T., K. R. Kimball, C. W. Hiibner, and J. M. Bagley.  
1983. Adapting water services to urban growth: A case study  
of Salt Lake County. UWRL/P-83/05, Utah State University,  
Logan, Utah.

REAL-TIME CONTROL AND DATA ACQUISITION SYSTEMS FOR REMOTELY  
LOCATED HYDROMETEOROLOGICAL DEVICES AND SENSORS

Abstract

The principles of remote control communications were applied to assess the strengths and limitations of available equipment options in satisfying data acquisition and system control needs and design a cloud seeding system.

Principal Investigator

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Support Personnel

Wayne Lofthouse (BS), Electrical Engineering  
Hans R. Miranda (BS), Electrical Engineering  
Hans Leineweber (BS), Electrical Engineering

Water resources data acquisition and management operations are moving increasingly to remote sensing and control, respectively. The control may either add flexibility to augment sensing capability or be used to implement timely management action. Water resources management operations that could be served by efficient remote sensing and informed response include automatic cloud seeding systems, automation of field irrigation systems or canal water delivery to large irrigated areas, operation of urban stormwater systems, and initiation of flash flood warnings or toxic pollutant alerts. Leaders in developing remote control technology generally lack expertise in water resources applications. Similarly, individuals responsible for water resources management are seldom conversant in the principles and latest developments in remote control technology. The need addressed by this project is to assemble a ready reference on the principles of remote control communications and on their application in comparison of alternative types of equipment so that equipment units with specific capabilities can be selected to match specific needs. The assessment will also describe the limitations imposed by FCC regulations, cost effectiveness considerations, and such technical aspects as the performance of mixed mode systems and methods for interfacing. People responsible for developing modern water resources management systems will then be better able to judge what can and cannot be done toward achieving their management goals and take fuller advantage of the capabilities of available equipment.

Research Project Accomplishments

Document has been made for a wide variety of options existing in available communications equipment for conveying data or instructions. Promising additional options under development by large corporations are also covered in the assessment of principles used and their strengths and limitations in specific applications.

Use of the reference is illustrated in a specific application of remote control tech-

nology to cloud seeding to enhance mountain snowfall. For the cloud seeding application, the design options have been analyzed and a preferred mode has been selected. This selection is based upon equipment available, FCC regulations, and cost. The present approach is to utilize the 72-76 MHz communication band along with specialized paging receivers. The logic for using the reference to reach this conclusion will be carefully documented as an example for users with other needs to follow.

### Application of Research Results

The project has produced a systematic analysis of the capabilities of present remote control equipment alternatives. An individual needing such equipment can define his need in terms of the parameters being used by manufacturers to specify the capabilities of remote control devices. The user can also determine whether it is possible to achieve desired goals, identify the alternatives for doing so, and examine their respective strengths and weaknesses. The person responsible for water-resource system operation

(whether for cloud seeding, field-irrigation water management, canal operation, stormwater management, or emergency warning) has available a reference that would save time in remote control systems design. Automated remote system operation is in the research stage, and the first users of this study will be researchers improving the efficiency of remote sensing-control systems in particular applications.

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U.S. Geological Survey Cooperative Program  
04/01/84 - 09/30/85  
Research Completed

### Publication

Hill, G. E., W. Lofthouse, H. Miranda, H. Leineweber. 1985.  
Remote control of hydrometeorological devices. UWRL/  
A-85/01, Utah State University, Logan, Utah.



**PART 4**

**SHORT REPORTS ON ACCOMPLISHMENTS  
BY RESEARCH PROJECT**

## PART 5

### HISTORICAL HIGHLIGHTS

#### Dates to Remember

1956

Congressman H. Aldous Dixon (former president of USU) introduced H.R. 10663, a bill which proposed that the Secretary of Agriculture be: "...authorized and directed to establish, maintain, and operate at such location as he deems desirable a regional water laboratory for the purpose of conducting research and study with respect to the physical laws, principles, and dominant variables affecting the source, supply and use of water...."

1957

The first research actually done on the laboratory site was by Cy Lauritzen who installed a pipe outlet to bring water from First Dam and conducted experiments on the hydraulics of flexible tubing.

1958

Dean F. Peterson and P. K. Mohanty, a student, initiated flume studies using large bed elements at the present laboratory site with hopes that continuing research at the site would increase the chances of getting a funded water research laboratory at Utah State.

October 14, 1958

Dean F. Peterson, dean of College of Engineering at USU, presented a University proposal for a federal water research laboratory to be located in Cache Valley to USDA at a public hearing on Soil and Water Research Facilities, held in Salt Lake City. The result was that the USDA put an irrigation hydraulics laboratory on their list of desired facilities.

1959

The Utah legislature authorized establishment of a water resources research laboratory at USU and initiated architectural planning.

1961

The Utah legislature entertained a bill legislation providing that there be: "...appropriated to the State Building Board \$1,200,000.00 or so much thereof, as may be necessary, from the General Fund for constructing the Utah Water Research Laboratory, on the Logan River, on property already acquired by the State of Utah for such purpose, the preliminary plans for which Research Laboratory have already been prepared by the Building Board...."

Subsequently, the building appropriation for USU for the 1961-63 biennium included \$200,000 for a "Hydraulics Laboratory."

1961

U. S. Senator Wallace F. Bennett introduced a bill to authorize the Secretary of Agriculture to: "...establish, equip, and maintain a regional research laboratory to be located at or near the Utah State University...."

1962/1963

Although nothing came of Bennett's 1961 bill, a bill was drafted and introduced by Senator Clinton Anderson of New Mexico in 1962 to establish water resources research centers at selected universities. Then in 1963, the bill was revised and introduced again. The legislation was enacted the following year and became known as the Water Resources Research Act of 1964. The program was administered by the Office of Water Resources Research (OWRR), U. S. Department of the Interior.

November 1963

Groundbreaking ceremonies were held, and building the Utah "hydraulics" laboratory began.

July 12, 1964

The USU Board of Trustees approved the appointment of Vaughn E. Hansen as the first Director of the Utah Water Research Laboratory.

November 21, 1964

An Official Charter for the Utah Center for Water Resources Research at Utah State University was approved by the Board of Trustees of Utah State University to coordinate the Utah portion of the OWRR program.

February 2, 1965

The UCWRR responsibility for the Utah water research program was officially designated to the Office of Water Resources Research.

December 6-7, 1965

The completed Utah Water Research Laboratory facility was dedicated.

June 30, 1966

Dr. Vaughn Hansen resigned his position as director, and was replaced by Dr. Jay M. Bagley in July 1966.

March-April 1968

A memorandum of agreement between Utah State University and the U. S. Department of the Interior for executing a portion of this program was signed April 8, 1968, by D. F. Peterson and March 26, 1968, by the Director of the Office of Water Resources Research.

June 12, 1970

An Advisory Panel was created to work with campus water leaders and programs in assuring a program of research that is coordinated with the state's needs. June 12 was the date of their first meeting.

July 1974

The Universities Council on Water Resources held their annual meeting on the Utah State campus at which Director Warren Hall of OWRR announced a name change to the Office of Water Research and Technology (OWRT), and the water center directors of the respective states organized the National Association of Water Institute Directors (NAWID).

July, 1975

Dr. Bagley resigned his position as director. Calvin G. Clyde was named Acting Director.

**July 1, 1976**

L. Douglas James became director of Utah Water Research Laboratory.

**March 1978**

Funds were authorized for adding modern water quality research laboratory facilities and student project space within the UWRL building.

**March 1979**

UWRL remodeling project was approved and the contract signed. Construction began in April.

**December 4, 1980**

UWRL building addition dedication was held.

**August 6, 1982**

The building that houses the Utah Water Research Laboratory was named the "George Dewey Clyde Building" in official ceremonies. The naming honors the former Governor of Utah, George Dewey Clyde, for his contributions to water research and development in Utah. His support of the Water Laboratory concept while he was governor made the enterprise possible.

**September 24, 1985**

The research program had been shifted in the Department of the Interior to the U. S. Geological Survey. Official certification was made as required by the provision of 30 CFR 401.6 of the establishment of the Utah Center for Water Resources Research at Utah State University to conduct the Utah water research program cooperatively with the U. S. Department of the Interior through the Office of Water Resources Research (1964), Office of Water Research and Technology (1974), Office of Water Policy (1982), the U. S. Geological Survey (1984), and any successor agencies. (Letter from Stanford Cazier USU President to Dr. Dallas L. Peck, Director U. S. Geological Survey, U. S. Department of the Interior, Reston VA.)